HEALTH AND SAFETY PROBLEMS AND WEATHER EFFECTS ASSOCIATED WITH ATOMIC EXPLOSIONS

HEARING

BEFORE THE

JOINT COMMITTEE ON ATOMIC ENERGY

CONGRESS OF THE UNITED STATES

EIGHTY-FOURTH CONGRESS

FIRST SESSION

ON

HEALTH AND SAFETY PROBLEMS AND WEATHER EFFECTS ASSOCIATED WITH ATOMIC EXPLOSIONS

APRIL 15, 1955

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
61504° WASHINGTON : 1955

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HEALTH AND SAFETY PROBLEMS AND WEATHER EFFECTS ASSOCIATED WITH ATOMIC EXPLOSIONS

FRIDAY, APRIL 15, 1955

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D. C.

The Joint Committee met at 11:20 a. m., pursuant to call, in room 457, Senate Office Building, Senator Clinton P. Anderson (chairman of the joint committee) presiding.

Present: Senators Anderson (chairman), and Hickenlooper; Representatives Price, Cole, and Hinshaw.

Present also: Corbin C. Allardice, executive director, Edward Heller, Wayne Brobeck, and Kenneth Mansfield of the professional staff of the joint committee.

Chairman ANDERSON. The meeting will be in order.

I want to explain that this meeting was somewhat hurriedly called because of the possible absence from the city of some of the people that we wanted as witnesses, and we either had to have this hearing now or postpone it quite a little while, and it was deemed desirable to have it now.

In early 1951 with the full concurrence of this committee, the Atomic Energy Commission set up a weapons test facility in Nevada in order to speed up our progress in nuclear weapon design. These tests and the laboratory results confirmed by them have been mainly responsible for the United States present position of preeminence in nuclear weapons. Without these tests we should not have progressed so far nor so fast in the weapons field and I think it is eloquently clear to all that in this grim race with the Communist world our position of preeminence is vital to the security of the free world. For this reason, today as in 1951, the committee wholeheartedly endorsed the Atomic Energy Commission's continental defense program. The committee has however been keenly interested in seeing that the public safety was protected at all times. To this end we have reviewed with the AEC before each test series the measures being taken to protect the public safety and have received assurances from the AEC that every prudent step to protect the public was being taken. The committee held executive hearings with the AEC last fall to review the safety measures planned for the current test series. We plan to continue this practice in the future.

This hearing has been called for the purpose of placing on the public record the facts, so far as they are known, about the radiation effects of the test explosions of atomic devices at the Nevada test site.

There is a great deal of public misapprehension and unwarranted concern about the radiological effects of the Nevada test explosions. The Commission's February 15 statement on the effects of high-yield

nuclear explosions, pointed out that the big tests were made only in the Pacific, not in Nevada, where much smaller devices and weapons are tested. Nevertheless, there has been confusion in the minds of many who seem to believe that the radioactive fallout from Nevada tests is as strong and carries as far as that from Pacific tests. This is not the case, as we of the committee know. But regardless of the small radioactivity from Nevada test fallout, there are those who believe that the Nevada tests bring on changes in weather; that they affect the physical inheritance of future generations and cause long-time hazards by leaving lingering radioactivity in the atmosphere or in the ground.

This committee has called this hearing for the purpose of placing before the Congress and the public a connected statement of the facts that may dispel misconceptions.

Today we are very happy to welcome the Chairman of the Atomic Energy Commission, Mr. Strauss, two new members who have probably not been in public hearings, as such, and one old member, Mr. Murray, who has been on the Commission a long time. Dr. Libby is a new member. Dr. von Neumann, I believe, is probably making his first appearance as a member of the Commission.

I think it would be very nice if General Fields were here.

Mr. STRAUSS. Mr. Chairman, he had to go back for an important matter, and I thought you would excuse him.

Chairman ANDERSON. I wanted to welcome General Fields to his new responsibilities as General Manager of the Atomic Energy Commission and express my personal conviction and, I am sure, the conviction of all of the members of the committee that he will do an outstanding job in keeping with the fine traditions we have had in that office.

There will be representatives of the Weather Bureau, Mr. Wexler and Dr. Machta, this afternoon.

Admiral Strauss, if you are ready, we will be happy to have your statement at this time, and we thank you for your prompt cooperation because we gave you very short notice. I would like to publicly express that thanks.

STATEMENT OF LEWIS L. STRAUSS, CHAIRMAN; ACCOMPANIED BY DR. W. F. LIBBY, COMMISSIONER, AND DR. JOHN VON NEUMANN, COMMISSIONER, ATOMIC ENERGY COMMISSION

Mr. STRAUSS. Mr. Chairman and gentlemen, I would certainly like to thank you for this introductory statement on behalf of all of my colleagues, Mr. Chairman, and also I would like to thank you for the opportunity that you have provided for us to clarify and to set straight the facts about radiation as they relate to the atomic tests currently being conducted in Nevada.

This open hearing serves a most useful and timely purpose. Radiation has become a characteristic of this age with great potentials for beneficial as well as destructive applications. Therefore the people must be informed of all the available facts about radiation as rapidly as they are scientifically determined. I believe that the Joint Committee and the Commission are in complete agreement on this. To this end the Commission will pursue its studies of the subject, in collaboration with scientific authorities outside the Commission, not alone

for the protection of life in the event of enemy attack where radiation exposure would be far greater than that involved in any tests, but for the promotion of safe, peaceful uses of this new source of energy which holds the promise of such great benefits for all mankind.

Since the Atomic Energy Commission's detailed report of February 15 last on the effects of high-yield nuclear explosions, there have been misapprehensions and speculation in some quarters which have tended to confuse the effects described in that report with the effects of the atomic tests currently being conducted in Nevada.

The February 15 report dealt with the March 1, 1954, explosion of a so-called H-bomb at Bikini atoll in the Pacific. The Bikini device produced an explosive force equal to millions of tons of TNT and deposited its radioactive fallout over an area of several thousand square miles. Such high-yield thermonuclear weapons as the one which formed the basis of the February 15 report are not tested in Nevada or elsewhere within the continental United States. Therefore, the effects described in that report do not apply to any atomic tests conducted in Nevada.

While it is true that there are radioactive particles in bomb clouds produced by the Nevada tests, this does not mean that dangerous radioactivity is scattered over offsite areas.

It is completely erroneous to assume that every nuclear explosion, regardless of size or point of burst, creates a fallout danger over thousands of square miles and ranging several hundred miles downwind from the point of burst. This is not the case. The explosion at Bikini occurred on the surface of the island. The fallout, therefore, resulted from both the tremendous explosive power and the fact that the fireball touched the surface of the earth. An atomic device of the type now being tested in Nevada detonated under the same conditions as those of the Bikini explosion would have produced only a very small fraction of the fallout. Likewise, if the Bikini H-bomb had been exploded high in the air, the particles would have been smaller and lighter than was produced by the surface explosion, and therefore, they would have been carried by the wind over a greater distance. This would have meant that when the tiny particles finally drifted to earth, and perhaps much earlier, they would have lost most of their radioactivity due to decay.

The yields, that is to say the energy release, of the atomic devices tested at the Nevada site are actually quite small by comparison with the thermonuclear weapons whose testing is confined to a remote area of the Pacific.

Many of the weapons tested in Nevada are tactical devices, designed for use by the armed services against comparatively small restricted targets.

In fact, it would take several thousands of the smallest of these Nevada devices to produce explosive energy equal to that of the Bikini H-bomb, the effects of which were described in the Commission's February 15 report.

Since the first tests were conducted at the Nevada site in 1951 more than 40 of these smaller atomic devices have been exploded.

So far as we are aware, no civilian has ever been injured as a result of these tests.

I would like to say here, however, that four members of the armed services—all of them participants in the actual test operations—did

receive eye injuries on site, that is to say, at the test site, during the Nevada test operations, in the years 1952 and 1953.

I am advised that the Department of Defense informed the Commission of this at the time. I was not then a member of the Commission and had no knowledge of this until I read it in the newspapers recently. The events, as I have said, occurred 2 and 3 years ago.

The Department of Defense advised that three of the military personnel received only minor eye injuries, and the fourth suffered serious eye injury through negligence in disregarding safety instructions.

These few regrettable accidents must be related, however, to the many thousands of personnel engaged in the tests who have received no injury from the tests themselves.

Chairman ANDERSON. Mr. Chairman, I am sure we appreciate that statement because there has been some public questioning about it. Am I correct in my understanding that these injuries were not due to radiation but due to light?

Mr. STRAUSS. That is my understanding, Mr. Chairman, but I would not like to be categoric on that point.

Can Dr. Bugher confirm that? Is that correct?

Dr. BUGHER. Light and heat; yes, sir.

Chairman ANDERSON. Thank you very much.

Representative COLE. Mr. Chairman?

Chairman ANDERSON. Mr. Cole.

Representative COLE. Mr. Strauss indicated that only four military personnel had been injured. In order that the record may be complete, does that mean that no civilian employees operating in connection with the tests were injured and that the four military constitute all personnel who have suffered injuries?

Mr. STRAUSS. That is my understanding, Mr. Cole. As a result of the tests, I believe that there have been what I would call ordinary industrial injuries—a person tripping over a wire or having a piece of heavy material fall on his feet, or things of that sort. I do not know the numbers or the extent, but the safety record of the Commission, as you are aware, is extraordinarily good in all of its activities.

Representative COLE. I am not quite clear whether you responded categorically to my inquiry or not. Do you mean that all of the persons injured by reason of radiation in connection with the tests were the four military personnel to which you have made reference, and no civilian employees or participants were injured?

Mr. STRAUSS. That is my information, Mr. Cole.

Representative HINSHAW. I understand, Mr. Cole, they were not injured by radiation, but by light and heat. I would change that question.

Chairman ANDERSON. I think what Mr. Cole is trying to get to, is whether that was an inclusive list regardless of the cause.

Mr. STRAUSS. I believe a purist would say that light and heat are also radiation, Mr. Cole. In using the term "radiation" I am assuming that we mean neutrons or gamma radiation from the blast itself.

The Commission's staff has reported on the basis of its nationwide monitoring, that the radioactive fallout from the Nevada tests, even in communities nearby the site, has never in any instance approached a level which is hazardous to health.

The fallout experienced by most American cities has barely added to the level of nature's normal background radiation which is always present in the soil, water, and air.

In this connection it is worth noting that radiation above normal background levels sometimes has been detected when no atomic tests have occurred. This is due to "cosmic showers," those periodic phenomena of nature which have been occurring for perhaps millenia without any known danger to the human race.

Rigid precautions are taken to hold the fallout from Nevada test shots to an absolute minimum. Suitable weather conditions are selected. This accounts for the not infrequent postponement in the current series. Methods of forecasting wind speeds and directions at various altitudes as well as the intensity and location of fallout have steadily improved since the first Nevada tests in 1951.

There has been speculation and concern in some quarters lest the Nevada atomic tests should affect weather conditions. Representatives of the Weather Bureau and advisers of the Atomic Energy Commission are here today, Mr. Chairman, and are prepared to discuss this phase of the subject. Therefore in this introductory statement I shall limit myself to saying that the Commission has worked in close cooperation with the Weather Bureau. We find no data to suggest that our weapons testing program has influenced weather conditions.

The American people can be assured that the rigorous safeguards which govern these tests are designed to prevent injury to the people of any community or city. The Commission has an extensive network of monitoring stations in areas near the test site as well as throughout the United States and is able to measure the levels of radioactivity by extremely sensitive methods. Daily information is received from more than 100 of these radiation detection installations which are operated by the Commission, the Weather Bureau, and the Public Health Service.

Radioactive fallout from the Nevada tests also is minimized by the manner in which the shots are fired. Most of the Nevada explosions occur well above the surface of the earth, with the result that only small amounts of earth are drawn up into the cloud. This is accomplished by exploding the devices atop towers, some as high as 500 feet, or by dropping the devices from planes for detonation at even higher altitudes.

As the basis of its safety criteria for all Nevada tests the Commission uses an "operational guide" of radioactivity which is very conservative and well within the actual limit of safety.

The Commission's February 15 report stated:

> In general, the total amount of radiation received by residents of the United States from all nuclear detonations to date, including the Russian and British tests and all of our own tests in the United States and the Pacific, has been about one-tenth of 1 roentgen. This is only about one one-hundredth of the average radiation exposure inevitably received from natural causes by a person during his or her reproductive lifetime. It is about the same as the exposure received from one chest X-ray.

The statement, as you will note, referred to all tests of all types of nuclear weapons by all countries to date. If we refer only to the current tests being conducted at the Nevada site we must speak—not of roentgens or even one-tenth of a roentgen—but of milliroentgens, that is to say, thousandths of a roentgen.

During the Nevada test series the radiation exposure from fallout, outside the actual testing area, has been well below the level that would constitute any actual hazard to the health of exposed individuals.

Generally speaking, the exposure experienced by the American people from the current Nevada tests has been less than the radiation they normally receive every few days from natural sources.

I would like now to refer briefly to the matter of genetic effects, which will be dealt with at length by Dr. Bugher and Dr. Green.

The Commission's February 15 report recognized that a wide range of opinion exists in regard to the possible effects which radiation exposure might have upon future generations. The report pointed out, first, that conclusive data are not available at this time on which to base an uncontrovertible forecast and, secondly, that the Commission would pursue its studies and continue to report the results to the American people.

Both before and after publication of the February 15 report discussion and speculation occurred on this subject in our own country and abroad, some of it by competent scientific authorities in the field of genetics, some by persons who have engaged in reckless and alarming predictions based on assumptions which go far beyond established scientific knowledge.

We know that the amount of radiation exposure from all nuclear tests up to now is only a small fraction of the exposure which occurs naturally from the soil, water, and air. Moreover, in considering the effects of radiation it should be borne in mind that over the ages the human race has been subjected to the continuous impact of radiation by cosmic rays and other natural phenomena.

Medical and biological advisers of the Commission are of the belief that the possibility of serious genetic effects from the small amount of additional radiation produced by the testing program is remote.

As further scientific knowledge is acquired more precise statements about the long-range genetic effect of radiation ought to be possible and will be made.

The Atomic Energy Commission has sponsored extensive research in the field of radiation genetics for a number of years and intends to continue this necessary research. The Commission supports about one-third of all federally supported genetic research carried on in the United States, and in addition, is engaged in extensive research in its own laboratories. The Commission is spending approximately $1.5 million a year on genetics research alone and will continue its thorough studies in this field and will report its findings to the American people as heretofore.

Within recent days the importance of such studies has been emphasized by the announcement that the National Academy of Sciences will undertake a broad appraisal of the effects of atomic radiation with financial support of the Rockefeller Foundation. This study is a timely undertaking and was discussed with the Commission before the arrangement was made. The Commission will facilitate this project in every way and will make available to the National Academy of Sciences the data which it has collected, both classified and unclassified.

We do not exclude the future possibility of some international undertaking for the same purpose but it is the Commission's belief

that greater and more prompt knowledge will be gained from the National Academy study than would be possible under international sponsorship. Furthermore, an international undertaking of this sort might be frustrated by world politics.

In conclusion, we must not lose sight of the fact that our security and the security of the free world is dependent upon the nuclear tests—both the testing of the so-called H-bombs in the Pacific and the smaller atomic devices in Nevada.

These tests involve more than the developing of atomic weapons, important though that obligation is. They provide vital data, which can be obtained in no other manner, on which to build a sound and effective system of civil defense against the eventuality of enemy attack.

Soviet Russia possesses atomic weapons; there is no monopoly for the free world. Therefore we have no alternative but to maintain our scientific and technological progress and maintain our strength at peak level. The consequences of any other course would imperil our liberty, even our existence.

The weapons which we test are essential to our national security and that of the free world; they have been and may well continue to be a deterrent to devastating war.

Mr. Chairman, that is the end of my prepared statement. As I mentioned a moment ago, Dr. Bugher, the Chief of our Division of Biology and Medicine, Dr. Green, who is our Chief Geneticist, Mr. Eisenbud, of our New York office, and, of course, the members of the Commission, are available for your questioning.

Chairman ANDERSON. Thank you. Are there any questions now before we call on Dr. Bugher?

Senator HICKENLOOPER. Mr. Chairman?

Chairman ANDERSON. Senator Hickenlooper.

Senator HICKENLOOPER. I would like to ask Chairman Strauss just one question for clarification. Is it not a fact, Mr. Chairman, that after an explosion occurs a great deal of the radiation is dissipated within a very short time by decay, so that the initial amount of radiation that is generated by an explosion rapidly diminishes in quantity and in intensity in a very short time? Is that correct?

Mr. STRAUSS. In the space of seconds or less.

Senator HICKENLOOPER. That is through decay?

Mr. STRAUSS. That is right, sir.

Senator HICKENLOOPER. And it is a comparatively small amount that might linger on for a long period of time?

Mr. STRAUSS. That is my understanding, Senator. I would like to take advantage of the fact that my scientific colleagues are here to ask that if I give an answer to a question of a technical nature with which they disagree, they will not wait to be called upon.

Senator HICKENLOOPER. The only point I was trying to make is that, let us say, "x" amount of radiation is released at the time of the explosion, or is created. Within a comparatively short time it is only a small fraction of that?

Mr. STRAUSS. That is right.

Senator HICKENLOOPER. Which still exists as a lingering increased radiation factor or quantity. I think it is important to make that clear.

Chairman ANDERSON. I think so.

Are there other questions?

Mr. STRAUSS. Dr. Libby, I think, would appreciate an opportunity to amplify my remarks.

Dr. LIBBY. I think a more quantitative answer might well be given, Senator Hickenlooper. The radiation dissipates at the rate of tenfold for every sevenfold increase in the age of the radioactive products. That is, at the end of 7 hours the radiation level is $\frac{1}{10}$ the level at 1 hour, and at the end of 49 hours, or roughly 2 days, it is $\frac{1}{100}$ of the level at 1 hour. This is the law which it follows. So it dissipates quite rapidly.

Senator HICKENLOOPER. In other words, it decays and ceases to exist?

Dr. LIBBY. Ceases to exist.

Senator HICKENLOOPER. Yes.

Chairman ANDERSON. Are there additional questions?

Representative COLE. Mr. Chairman?

Chairman ANDERSON. Congressman Cole.

Representative COLE. Has any information with respect to the genetic effects of atomic tests, nuclear explosions, been withheld from public disclosure?

Mr. STRAUSS. It is my understanding, Mr. Cole, that no information which has been evaluated to the point that it has become established scientific information has been withheld from the American public or from the world on genetic effects.

Representative COLE. I have one other question in order to complete my understanding of the extent of Federal expenditures in research in the field of genetics. You have indicated the Commission spends a million and a half directly in this program?

Mr. STRAUSS. Yes.

Representative COLE. And supports other Federal activities in genetic research to the point of one-third. Can you give us in dollars what that one-third amounts to so we can have in our minds the total expenditure by the Federal Government for research in genetic effects of nuclear explosions?

Mr. STRAUSS. Including the million and a half in our laboratories, the total is about $4.5 million per annum.

Representative COLE. That is all, Mr. Chairman.

Chairman ANDERSON. Are there additional questions?

Thank you, Mr. Chairman.

Dr. Bugher.

STATEMENTS OF JOHN C. BUGHER, M. D., DIRECTOR, DIVISION OF BIOLOGY AND MEDICINE; DR. E. L. GREEN, GENETICIST, DIVISION OF BIOLOGY AND MEDICINE; MERRIL EISENBBUD, MANAGER, NEW YORK OPERATIONS OFFICE, AND DIRECTOR, HEALTH AND SAFETY LABORATORY, ATOMIC ENERGY COMMISSION

Dr. BUGHER. Mr. Chairman, thank you very much.

The direction of the nuclear tests upon which must depend the development of weapons adequate to maintain the security of the United States is a complicated and difficult task. Not only must we be concerned with the safety of thousands of scientists, engineers,

and craftsmen who must conduct these difficult operations, but also we must give great attention to insure the safety of people who have no direct connection with the test organization.

The forces released in even the smallest nuclear explosion are very great. Blast, light, heat, and nuclear radiation may be transmitted to considerable distances. In general, the danger diminishes very rapidly with distance but it has still been necessary to caution people near the proving ground not to look at the fireball through binoculars, not to stand near windows at the time of expected detonation and not to expose themselves needlessly to nuclear radiation. Some minor damage has been done; for example, window glass has been broken in Las Vegas and Indian Springs. A small number of horses and cattle which were grazing adjacent to the proving ground, at the time of the detonation, have been injured.

Radioactive fallout has been readily demonstrable in many of the nearby communities and on one occasion there were a few small communities which received a total environmental exposure slightly greater than the announced operational guide. These matters were all published in the semiannual reports to the Congress which are public documents and constitute valuable sources of detailed information about the operations of the Atomic Energy Commission.

Some claims for damage have been made. These have all been carefully investigated and where the evidence has given a reasonable basis for the conclusion that damage had in fact occurred, responsibility has been acknowledged and compensation negotiated. In other instances it has been difficult to determine the cause of losses which have been sustained. In these cases long and laborious studies have been undertaken. One of the best examples was the problem occasioned by the heavy loss of sheep in southern Nevada and Utah during and following the 1953 test series and erroneously attributed to the tests. Examination of numerous animals taken in conjunction with a thorough knowledge of the part of the country in which the herds had been wintered, made it possible to state the degree to which these animals had been exposed to radioactivity. It was concluded, from all of the scientific evidence obtained, that while there had been some small exposure of the sheep to radiation, this could not have been a contributing factor in the losses which the ranchers had experienced.

Senator HICKENLOOPER. Would you mind an interruption at that point, Doctor?

Dr. BUGHER. No, sir.

Senator HICKENLOOPER. Your statement is:

> It was concluded, from all of the scientific evidence obtained, that while there had been some small exposure of the sheep to radiation, this could not have been a contributing factor in the losses which the ranchers had experienced.

Was the prime or the chief cause of the loss determined by any branch or agency of Government?

Dr. BUGHER. Not fully, Senator Hickenlooper. The studies are still going on, because they deal with the problems of range management in the presence of drought conditions. Drought conditions obtained at that time, and have persisted to some extent since then. The problem is one of nutrition, a problem of a grazing animal turning to foodstuffs, that is, plants, that normally the animal does not browse on. Thus it is a complicated situation.

Senator HICKENLOOPER. Thank you very much.

Chairman ANDERSON. But, in any event, you are sure it was not due to radiation?

Dr. BUGHER. Yes, sir.

Collection of the vast amount of data necessary to answer these and many other specific questions has involved the cooperative efforts of many groups of people. Among these a vital role has been played by the United States Weather Bureau, which has had an active participation in the system for the measurement of radioactive fallout over the United States since early 1952 although the Bureau's general interest in the testing program was manifest from 1948 onward.

In 1952 it became apparent that additional research was required in connection with the prediction of the approximate trajectories of atomic bomb debris. Accordingly, a research program was undertaken by the United States Weather Bureau with the support of the AEC and is still continuing. The Weather Bureau also plays an important role in the operation of the AEC's nationwide monitoring system. By arrangement with the Health and Safety Laboratory of the AEC, 89 Weather Bureau stations throughout the Nation collect fallout samples which are forwarded to the Health and Safety Laboratory for analysis. The Director of the Health and Safety Laboratory, Mr. Merril Eisenbud, is with us today, and is prepared to describe in greater detail the operation and findings of the nationwide monitoring system, should the committee desire.

The apparently high incidence of tornadoes during the spring of 1953, coincident with the testing of atomic devices in Nevada at that time, prompted a number of inquiries by the public as to a possible relationship. As a result, the Atomic Energy Commission and the Weather Bureau entered into a joint project for the purpose of analyzing all relevant factors of atomic tests for possible bearing on weather in general and tornadoes in particular. Witnesses from the Weather Bureau will discuss this subject.

By means of the network of stations which has been operated for the last 3 years and toward which the Weather Bureau has made a substantial contribution in effort, it is possible to speak today with a sure knowledge of the degree to which radioactive material from weapons tests has descended on all parts of the United States. With the exception of certain atolls in the Marshall Islands the United States has been the recipient of considerably more radioactive material than any other country of which we have knowledge.

As the measurement of radioactive fallout has progressed the essential results have been published. In the Commission's February 15 statement it was reported that the total cumulative external gamma exposure to people in the United States from all tests of all nations amounted on the average to 0.1 roentgen. We can further state, as result of many careful analyses that strontium 90, the most troublesome fission product of long half-life, is present in the population to a value that does not exceed one one-thousandth of the presently accepted permissible level for this isotope. These quantities while exceedingly small are capable of precise detection and measurement.

At the present moment, the activity throughout the United States from bomb debris resulting from all past tests amounts to 0.2 percent of the natural radioactivity contributed by cosmic rays and radium and radon of the earth's surface, together with postassium 40, which is a normal component of all living things.

Not only have the land areas been explored but extensive operations have been undertaken at sea. For years the marine biologists at the University of Washington have been studying the effects of the operations at Bikini and Eniwetok on the fauna of those islands. In addition to the Applied Fisheries Research Laboratory at the University of Washington, the Commission supports marine work at the University of Hawaii and has constructed and made available to biologists a marine biological station on Eniwetok itself.

During these recent weeks a team of scientists from Atomic Energy Commission's Health and Safety Laboratory and from the Scripps Institution of Oceanography, and the University of Washington, Seattle, has been working aboard the Coast Guard Cutter *Taney* under the command of Comdr. Albert J. Carpenter. This expedition has been measuring the residual radioactivity in the waters which have been flowing westward from the Marshall Islands since the Castle operations last spring. By employing very sensitive and precise instrumentation they have been able to demonstrate the presence of small amounts of radioactivity for several thousand miles and have been able to develop new knowledge concerning the rate at which the waters of the Equatorial Current mix both horizontally and in depth. This expedition was conducted, first, as a part of the effort to obtain quantitative knowledge of the radioactivity previously released and, second, to utilize the presence of activity as a tracer system for studying the ocean currents. This party has now reached Japan, having worked the last few days in waters in which they were unable to detect an increase in the background radioactivity.

The maximum water contamination which they encountered gave about 120 disintegrations per minute per liter. Such a figure as this is well within the standards for drinking water and for continuous consumption adopted by the National Committee on Radiation Protection and the corresponding International Commission. Studies such as this are complex since they must extend to the various food chains that exist in the ocean. They become important to man, how ever, only when they involve such portions of the ocean life as he may use for food.

This then is the quantitative environmental situation as it exists today from all tests heretofore performed. The other part of our inquiry must obviously deal with the effects of these low levels of exposure on human beings. Hence, we must distinguish the general environmental effects from the accidental exposure of a number of people in the Marshall Islands last March 1. Not only were Marshall Island residents and task force personnel involved but also a number of Japanese citizens in a fishing boat. Among these were obvious and serious injuries occurring from general exposure of the order of 175 roentgens combined with an additional skin exposure of at least 4,000 roentgens equivalent to the lower levels of the epidermis. This is of a completely different order of magnitude from the average exposure of the American people of about 0.1 roentgen from all tests.

What may we say with reasonable accuracy concerning the effects or lack of effects of exposure of this minimal character?

In the first place we know of no evidence that exposure to radiation ever is beneficial to normal tissue. This however has no bearing on the question of the value of radiation therapy in the treatment of disease. Since radiation is never beneficial to normal tissue it is

always desirable to minimize any exposure and that has been the consistent policy of the Atomic Energy Commission in all of its activities. As with any injurious or toxic agent there are levels at which one cannot detect a significant change or injury. It cannot be said that below this level nothing whatever occurs. We simply say that if injury occurs, our methods are insufficiently sensitive to detect it and presumably as far as that individual is concerned, whatever change there may be is unlikely to have any important consequence to him.

For practical operating purposes we may arbitrarily take a value for radiation exposure which is considerably less than the level at which effects are detectable and say that this will be acceptable as a maximum permissible exposure. At such a reduced level, there would be extremely small probability of any recognizable effects at all.

It is at this point that some confusion tends to arise and is typified by the meaning of the word "hazard." To the radiation protection expert the word "hazard" is commonly used to refer to a finite statistical probability of injury even though the likelihood of encountering anyone with such an injury might be extremely small. To the nonscientific person or the nonspecialist the word "hazard" connotes a clear and present danger and is likely to be interpreted as referring to a reasonably probable injury affecting himself, some member of his family or those immediately about him. These two points of view are each in themselves consistent but are poles apart in meaning. This is but one of many possible examples in which an exact scientific statement satisfying to the specialist, has an entirely different meaning for the nonscientific but well-informed citizen.

The important radiation effects in man fall into two broad groups, one pertaining to the individual himself and the second related to questions of inheritance of results of radiation damage to the germ cells. The first category we may call somatic and the second the genetic effects.

Somatic effects: In all situations so far encountered, and especially in the areas close to the detonation, the external gamma exposure is overwhelmingly more hazardous than that from the internal ingestion of radioactive bomb products. The immediate effects of whole body gamma radiation are determined by the dosage received and the rate of delivery. The systems most fundamentally affected are the central nervous system, blood-forming organs and tissues and the gastrointestinal tract. For radiation promptly delivered, transient depression of white blood cells and platelets may be detected at an exposure of 50 roentgens and nausea and vomiting will occasionally be found with whole body doses as low as 100 roentgens.

Where the dose is delivered over periods of weeks to months the total amount of radiation received before there is recognizable change is many times the dose that is lethal when delivered within a few minutes. Where exposures of several hundred roentgens occur, it seems clear from the results of the study of the survivors of Hiroshima and Nagasaki that there is an increase in the frequency of leukemia. The increase is marked only in proportion to the normal frequency of the disease. The actual number of all such cases will be detectable only when a large population is studied. From heavy doses of gamma radiation it seems possible and perhaps probable that there will be a statistical shortening of life expectancy, again to be appreciated only

by the most meticulous study of a large population. Such factors require hundreds of roentgens to be detectably increased and we see no possibility whatever of recognizing such effects at the exposure levels from radioactive fallout from tests.

Genetic effects: Radiation may not only damage the somatic cells but by acting upon certain stages of the germ cells may give rise to alteration of the genes upon which inheritance depends. It appears that there is no definite threshold for this effect and that there is a linear relationship between the frequency of the gene changes and the total irradiation. At the present time, it seems that the rate at which the radiation is given is a minor and perhaps negligible factor.

The quantitative studies have necessarily been made with relatively high exposures varying from a minimum of 50 roentgens with mice to a maximum of several thousand roentgens in the case of the more resistant fruitfly. Each species has its own range of sensitivity.

If one assumes that the linear relationship which has been experimentally determined holds for all exposures however small, then the extrapolation of the data leads to the conclusion that a small but finite probability exists for gene mutations at the level of the radioactivity of the natural environment. That mutations do occur in all living things is well established and indeed forms the basis for all evolution. At present, however, we do not know to what extent the normal mutation frequency is caused by the radioactivity of the natural environment and what is due to other factors.

The second area of uncertainty has to do with the ultimate effect of mutation rates on the welfare and survival of populations. Since many of the important mutations appear to be dominant lethals, their estimation has to be based, not upon the recognition of anomalous characters, but on the estimation of the numbers of individuals who should exist, but in fact, do not. The technique, which is very useful in laboratory experiments with animals, becomes very difficult of application to a human population for obvious reasons.

Some of the mutations may be recessive and consequently not be detectable until at some future time when an individual carrying such a mutant gene should mate with another individual carrying the identical factor.

The occurrence of mutations is only part of the problem. The fate of the mutations in populations is another important question. These mutations will be subjected to the same forces of natural selection that now act against spontaneous mutations, and may be expected in time to disappear.

The extremely complicated and difficult genetic problem in man constitutes a very important section of the studies being conducted in Japan. No firm conclusions can be given until the statistical work is finished but it seems possible that some evidence of genetic effect will have been obtained among the more highly irradiated survivors at Hiroshima and Nagasaki. At the lower exposure rates, it is quite evident that no changes can be recognized.

Before I give a summary, Mr. Chairman, I would like to request Dr. Green to develop this subject somewhat more in detail. Dr. Green is associate professor of zoology at Ohio State University, on leave to serve the Atomic Energy Commission. He acts at Ohio State University as the faculty member directly responsible for the teaching and research in genetics.

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Chairman ANDERSON. Possibly it would be well to have his statement before we ask you any questions then.

Dr. BUGHER. That would be very good.

Chairman ANDERSON. Dr. Green, we will be happy to hear from you.

Dr. GREEN. Mr. Chairman:

The biological effects of radiation are not limited to the exposed individuals. Descendants of exposed people may show genetic effects of radiation. What we need is the best obtainable estimate of the magnitude of the genetic effects of radiation, taking into account the results of research extending over several years and also the various areas of uncertainty which still exist.

Each living person is the product of the genes, or hereditary material, he received from his parents. Several thousands of genes are transmitted from parents to offspring, usually without change. A gene may change, or mutate, once in a while under natural conditions so that the genes of the offspring are different from those of the parent. This has been going on since life began. Radiation is known, among other agents, to produce gene changes or mutations. The frequency of mutation of genes is proportional to the amount of radiation received by the cells of the sex glands. For genetic effects, the total amount of irradiation received before parenthood is important, not the rate of exposure nor the duration of exposure.

Genetic experiments with animals suggest that for a billion genes about 5,000 will mutate spontaneously or without assignable cause in each generation. If the billion genes are exposed to 1 unit of radiation (i. e., 1 roentgen), about 100 to 200 more genes may mutate. The average level of radiation from all tests of atomic weapons to date is about one-tenth of this unit of radiation. Thus instead of 5,000 mutations, there may have been 5,010 or 5,020 mutations in a billion genes. A billion genes may be taken to represent about 100,000 organisms. It should be reemphasized that these estimates may be either too low or too high, since they are based upon animal experiments.

Gene mutations induced by irradiation are usually deleterious. Since the term "deleterious" has a special meaning here, it should be explained. The term refers to the effects of the genes on development, growth, and survival of individuals. It is also important to distinguish between two cases: First, when a gene with deleterious effects occurs in both parents and, second, when it occurs in one parent only. If a deleterious gene mutation is induced and if an offspring receives the same mutation from both parents, it may have a very low probability of survival. In large outbreeding populations of mankind, the chance of receiving identical radiation-induced mutations from both parents is very, very small. The occasions when this may happen as a consequence of present levels of radioactivity from tests will be so rare and spread out over so many thousands of years that a detectable effect on birth and survival rates is unlikely. If an offspring receives a deleterious mutation from only one of its parents, it may be totally unaffected, or in a few cases it may show some observable harm, or its chance of survival may be reduced by 5 or 10 percent. This is the more important case. Numerically these may still be so few as to be lost among the varied types of offspring being produced as a consequence of genetic and other causes. So long as the amount of radiation is low, the genetic risk is correspondingly low.

Dr. BUGHER. Mr. Chairman?

Chairman ANDERSON. Dr. Bugher.

Dr. BUGHER. I would like at this time, in continuing with this formal statement, to call on Mr. Merril Eisenbud, if the committee, is willing, to give additional factual material concerning the detection measurement of fallout and the documentation of that over the country.

Chairman ANDERSON. Mr. Eisenbud.

Dr. BUGHER. May I say that Mr. Eisenbud not only serves the Commission as manager of the New York operations office, but directs the scientific work of the extremely important health and safety laboratory which has been so fruitful in the development of new instrumentation and new methods of analyzation.

Mr. EISENBUD. Fallout radiation has been measured systematically by the AEC since early 1951. Two basic systems for collecting data have been employed:

(*a*) Intensive monitoring of the area relatively close to the sites of detonations, about 200 miles radius from the test site in Nevada. In this region, radiation data are gathered after each blast by a variety of techniques, including (1) aircraft which are equipped with instruments that measure the ground level radiation; (2) instruments that record the radiation levels and automatically transmit the data to a headquarters by radio or telephone; and (3) manually operated radiation detectors. The monitoring system in this region is primarily concerned with measuring the short-term dose from fallout. Being close to the site of detonation, the fallout may occur in this region within a few hours after the burst, at a time when the radioactivity is decaying rapidly and most of the dose is delivered in a day or so.

(*b*) In contrast, at more distant locations the monitoring system is designed to document the low-level fallout that is insignificant so far as immediate dose is concerned. When tests are underway in Nevada, a nationwide network of 89 stations provide a continuous record of fallout for the area of this country beyond 200 miles.

(The list of stations referred to follows:)

NETWORK OF UNITED STATES COLLECTION STATIONS (FEBRUARY 1955)

Mobile, Ala.
Montgomery, Ala.
Flagstaff, Ariz.
Phoenix, Ariz.
*Tucson, Ariz.
Yuma, Ariz.
Fort Smith, Ark.
Eureka, Calif.
Fresno, Calif.
*Los Angeles, Calif.
Sacramento, Calif.
San Diego, Calif.
*San Francisco, Calif.
Colorado Springs, Colo.
Denver, Colo.
*Grand Junction, Colo.
Pueblo, Colo.
*New Haven, Conn.
*Washington, D. C. (Silver Hill, Md.)
*Jacksonville, Fla.
*Miami, Fla.
*Atlanta, Ga.
*Boise, Idaho
Pocatello, Idaho
*Chicago, Ill.
*Des Moines, Iowa
Concordia, Kans.
Goodland, Kans.
*Wichita, Kans.
*Louisville, Ky.
*New Orleans, La.
Caribou, Maine
Baltimore, Md.
*Boston, Mass.
Alpena, Mich.
*Detroit, Mich.
Marquette, Mich.
Grand Rapids, Mich.
*Minneapolis, Minn.
Jackson, Miss.
*Kansas City, Mo.
*St. Louis, Mo.
*Billings, Mont.
Helena, Mont.
Kalispell, Mont.
*Scottsbluff, Nebr.
Elko, Nev.
Ely, Nev.
*Las Vegas, Nev.
Reno, Nev.
Winnimucca, Nev.
*Concord, N. H.
*Albuquerque, N. Mex.
Roswell, N. Mex.
Albany, N. Y.
*Binghamton, N. Y.
*Buffalo, N. Y.
*New York (LaGuardia), N. Y.
*Rochester, N. Y.
Syracuse, N. Y.
*Cape Hatteras, N. C.
Fargo, N. Dak.
Williston, N. Dak.
*Cleveland, Ohio
*Medford, Oreg.
Portland, Oreg.
*Philadelphia, Pa.
*Pittsburgh, Pa.
Providence, R. I.
Charleston, S. C.
Huron, S. Dak.
*Rapid City, S. Dak.
*Knoxville, Tenn.
*Memphis, Tenn.
Abilene, Tex.
Amarillo, Tex.
*Corpus Christi, Tex.
*Dallas, Tex.
Del Rio, Tex.
Port Arthur, Tex.
Milford, Utah
*Salt Lake City, Utah
Lynchburg, Va.
*Seattle, Wash.
Spokane, Wash.
Green Bay, Wis.
Milwaukee, Wis.
Casper, Wyo.
Cheyenne, Wyo.

*Stations in operation during Castle, the Pacific tests conducted in spring 1954.

Mr. EISENBUD. This network records the daily fallout of radioactive dust. Only on infrequent occasions can such a determination be made directly with instruments located at the place of fallout. The normal radioactive background in the United States varies from about 0.01 to 0.05 milliroentgens per hour. At these very low levels of activity the Geiger-Mueller or the scintillation counter, operated by a skilled observer, could perhaps indicate an increase of 50 percent over the normal background. In most cases, it would not be known whether this increase was due to fallout or due to the natural variations in radioactive background that occur daily. Moreover, these small elevations of radioactive background, although minute, would not be a sufficiently sensitive indicator for our purposes. Fortunately, it has been possible to develop a method of monitoring which is at once exceedingly simple and relatively inexpensive and more sensitive than direct instrumental monitoring procedures. Whereas, it would

be more difficult, as noted, to record an increase of 0.001 milliroentgen per hour with even the best radiation detection equipment, the method which we have used routinely is sufficiently sensitive to permit a measurement of fallout equivalent to 0.00001 milliroentgen per hour.

Our procedure is a simple one. We mount a 1 square foot gummed surface about 3 feet from the ground. The sticky surface retains its adhesive properties when wet: Thus, dust particles are retained even during a rain. These gummed films are tended by personnel of the Weather Bureau. The films are changed each day and are mailed to the AEC health and safety laboratory in New York, where their radioactivity is assayed by reducing the gummed film and the adhering dust to a small amount of ash which is then assayed for radioactivity by conventional laboratory counting equipment.

Since 1951, we have assayed over 200,000 samples in this way. An interim cumulative account of our findings was published in the scientific literature in 1952. A further summary up to January 1, 1955, has been compiled and is scheduled for publication during the next few weeks. The information has been available on request to many interested persons who have wanted the information for a variety of purposes. These individuals include representatives of the photography industry and scientists working in fields such as carbon 14 dating.

The cumulative fallout in the United States from early 1951 to January 1, 1955, varies from 21 millicuries per square mile in Arizona to 120 millicuries per square mile in New Mexico. As a basis for comparison, it is of interest to point out that the upper foot of soil in the United States contains about 1,000 millicuries of radium per square mile.

The isotope strontium 90, which is present in fallout, is regarded as the constituent of principal biological significance. This is because, like radium, it follows calcium into biological systems and may be deposited in the skeleton, from which it would be removed very slowly. The strontium content of the soil here in eastern United States now contains about 1 millicurie per square mile of strontium 90. This for all detonations up to about January 1, 1955. We thus conclude, from all tests to date, that this isotope is present in an amount about one thousandth the amount of natural radium, the natural radioactive substance to which it is chemically and biologically similar.

Mr. EISENBUD. Mr. Chairman, if I might have another 2 minutes for an informal presentation, I should like to acquaint the committee with the instruments and techniques that we use for this documentation.

(Mr. Eisenbud then demonstrated the equipment illustrated on pp. 18 to 21.)

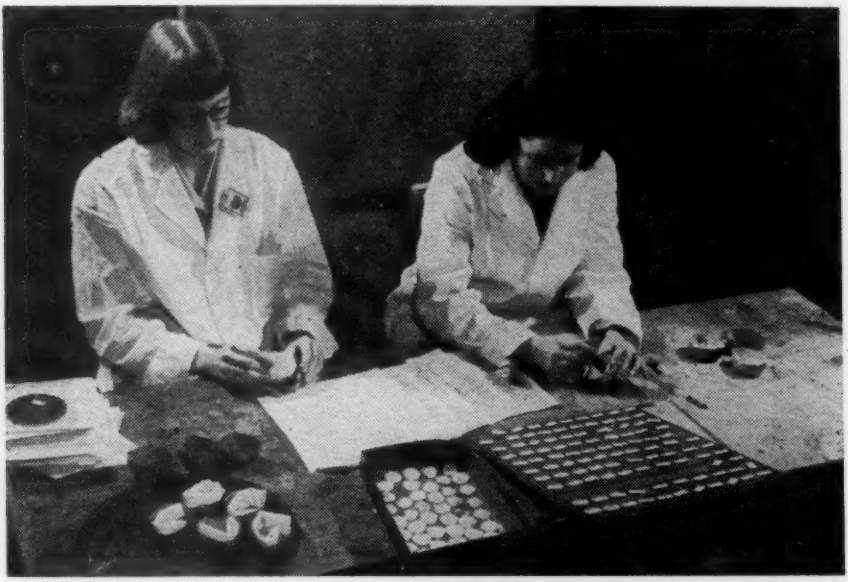
Chairman ANDERSON. Do I understand correctly that you have got a large number of stations around the country as indicated in your report, and that if there were, by some accident or combination of circumstances, a sufficiently large fallout that could be somewhat dangerous to public health, you would know about it pretty quickly from this source?

Mr. EISENBUD. No, sir. This system is not designed for that purpose. As I mentioned, the fallout which occurs beyond a few hundred miles from the test site is so insignificant that it could not be measured with instrumentation directly on site.

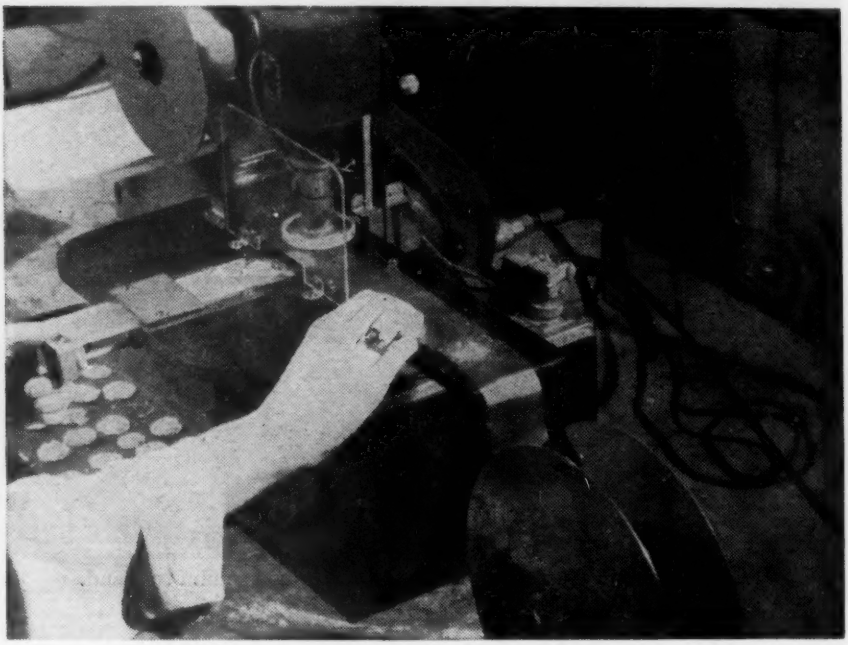
FALLOUT COLLECTION TRAY

A latex covered plastic film, 1 foot square, on a stand 3 feet above the ground, collects falling dust which adheres to the latex and is not removed by wind, rain, heat, or cold. Every 24 hours the film is changed, and the exposed square is folded on itself, sealing adhesive portions together, and mailed to the AEC's health and safety laboratory in New York for measurement.

This photograph illustrates method of attaching the film to stand.



In the New York operations office, a technician (left) folds collected samples and places them in crucibles for burning in a furnace. The technician on the right is grinding the ash from the furnace and placing it in numbered planchets for measuring by a special machine.



The numbered planchets are sealed between two rolls of polyvinyl tape at 8-inch intervals.

AUTOMATIC BETA MEASURING FALLOUT ACTIVITY COUNTER

Ashed samples, sealed in planchets between two rolls of vinyl tape, are loaded on this automatic beta counting device which measures their radioactivity and permanently records the information. The unit requires no attendant and processes more than 100 samples per day at the AEC's health and safety laboratory in New York.

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There have been exceptions. On six occasions—Troy, New York, Chicago, Rochester, Salt Lake City twice, and one more that escapes me, where the background radiation was elevated to about 1 milliroentgen per hour. This is high enough so that it can be read by conventional equipment, and in order to provide for this possibility, there is a secondary network, which I did not describe, which consists of well-informed observers located in universities all around the country. These individuals have been asked by the Commission to monitor the gamma radiation daily and report increases above five times normal, to A. E. C. Thus, for most parts of the country, this would mean that if the background radiation increased to about two-tenths of a milliroentgen per hour, the Division of Biology and Medicine here in Washington would receive a report.

Chairman ANDERSON. As far as the general public is concerned, is there a possibility that there could occur a deposit of radioactive material as a result of rain or some other cause that would be dangerous to the public health without your finding out about it pretty quickly?

Mr. EISENBUD. No, sir; this could not happen. The explanation perhaps was not clear that beyond several hundred miles from the test site, and this means roughly about 300 miles from the test site, the highest radiation levels that have been recorded to date are about 1 milliroentgen per hour. This is several thousands of times

Mr. EISENBUD. No, sir; this could not happen. My explanation below the value that would produce a deleterious effect. We have a safety factor of several thousand of times over the highest value that has been observed in the 40 or so tests.

Chairman ANDERSON. I am sure the Chairman senses what I am trying to determine.

Mr. STRAUSS. Yes, Mr. Chairman. You are right in this respect: There is an arrangement whereby excessive radiation, if it occurred, would be detected. Actually, we utilize several systems, one of which is the telemetering system which Dr. Bugher could demonstrate, if you wish, whereby we can call up a number of stations which can automatically, without anyone in attendance, register the condition of radiation at that particular moment. We are prepared, if you care to see a demonstration of it, to call Reno, Nev., or some other place at some distance and get an immediate reading of the radiation at that point.

Chairman ANDERSON. Reno would be an excellent spot from which to get a radiation report, I am sure.

Senator HICKENLOOPER. I was going to ask for Des Moines.

Chairman ANDERSON. Let us have Des Moines.

Mr. STRAUSS. Have you got one in Des Moines?

Dr. BUGHER. Mr. Chairman, these 26 stations have been established within the zone where we have occasion to be most concerned with immediate fallout problems, and the most remote one is probably Salt Lake City. So we do not bring them as far east as Des Moines, although the system is physically capable of nationwide coverage. There are 26 of them ringed around the Nevada test site in Utah and Nevada.

Chairman ANDERSON. Can we get Reno on the line now?

Dr. BUGHER. The call is going through to Reno, and while that is going on perhaps I might tell you how this system works?

Chairman ANDERSON. Yes.

Dr. BUGHER. The equipment which you see in the back (see pp. 24, 25, and 26) here was developed by the Radiation Instruments Branch and the National Bureau of Standards, working together. The principle is that a radiation detector can be connected with an electronic circuit so that the oscillations of the electronic circuit can be controlled in their frequency by the amount of radiation which the detector perceives. So that the oscillations which we are concerned with are placed in a sequence of frequencies which are recognized as different radiation levels.

So the call is going through to the Reno telephone long-distance operator to call a number on a line that goes out of Reno. At the end of that line is an automatic responder which will connect the line to the piece of equipment. The equipment will send back a signal which is an audiofrequency tone, and the pitch of that tone, of course, is determined by the frequency. There is a little loudspeaker attached to this instrument which would enable us to hear it.

The first thing that the station does is to identify itself by its own special frequency. It then proceeds to give us some signals which are calibration signals to make sure that its internal functioning is correct. Then it switches to give a signal from the radiation detector. All of those are printed out here by a device which counts the pulses precisely for 1 second and then transfers them to a printer which prints out the number that it has counted.

Senator HICKENLOOPER. It seems to me this is something like a television program where they call up from the studio, and if you are on the other end of the line and answer the question correctly, you get a Christmas present or something.

Chairman ANDERSON. Again to return to this question, Dr. Bugher, because I know you are very familiar with this whole story—would it be possible for the people, let us say, in Salt Lake City to be subjected to such a dangerous dose of radioactive material that it might be extremely injurious to their health and you not be able to find out about it?

Dr. BUGHER. No, sir; it would not be possible.

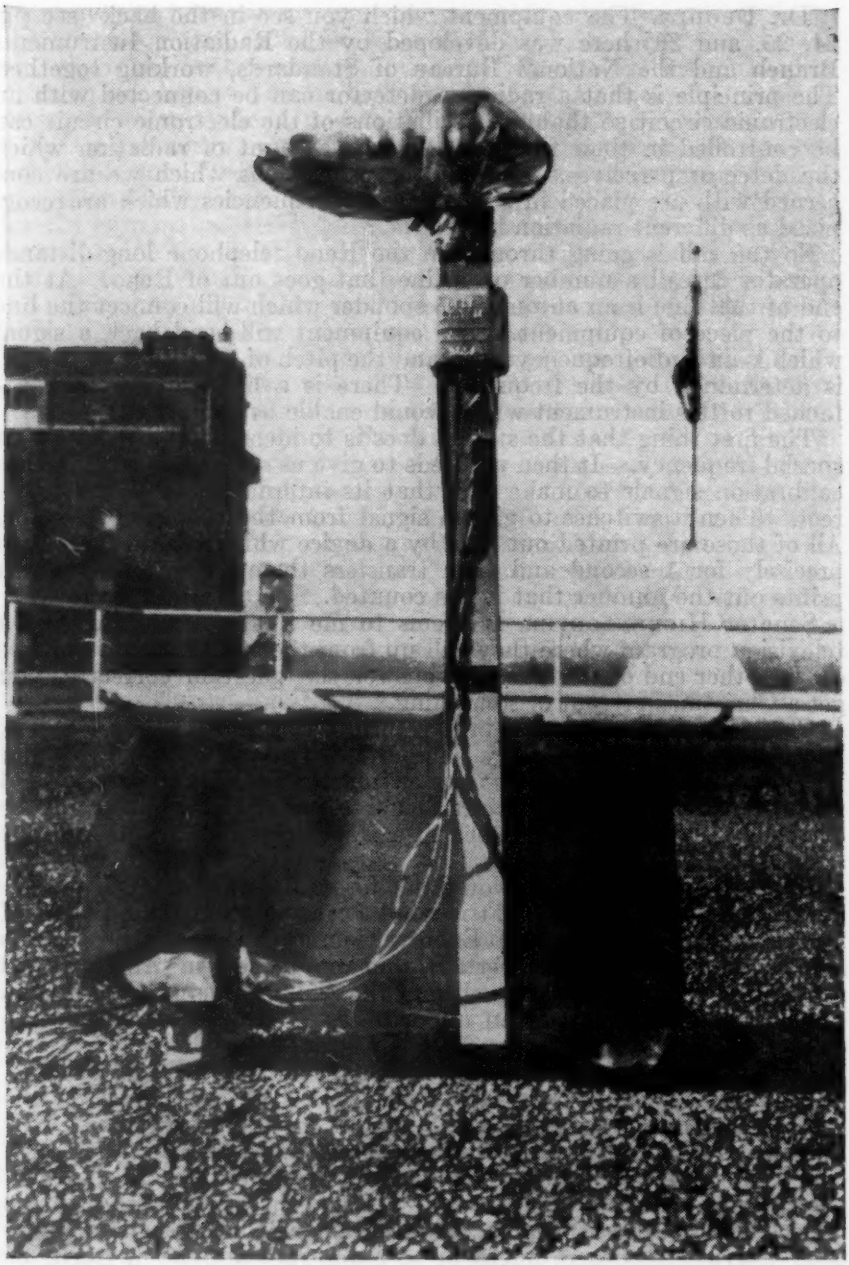
Chairman ANDERSON. That is what I was sure of. I think one of the fine things the Atomic Energy Commission has done in this field is to make it almost certain that no person in America will suffer from that sort of thing without the Atomic Energy Commission learning of it and having an opportunity to warn them about the dangers. Your system works to that degree, does it not?

Dr. BUGHER. We do not rely, Mr. Chairman, on any one system. In addition to these that have been described, we requested the Public Health Service to set up teams in these various cities. Salt Lake City is an example. We also have requested all of the AEC operation centers to keep in touch with the situation.

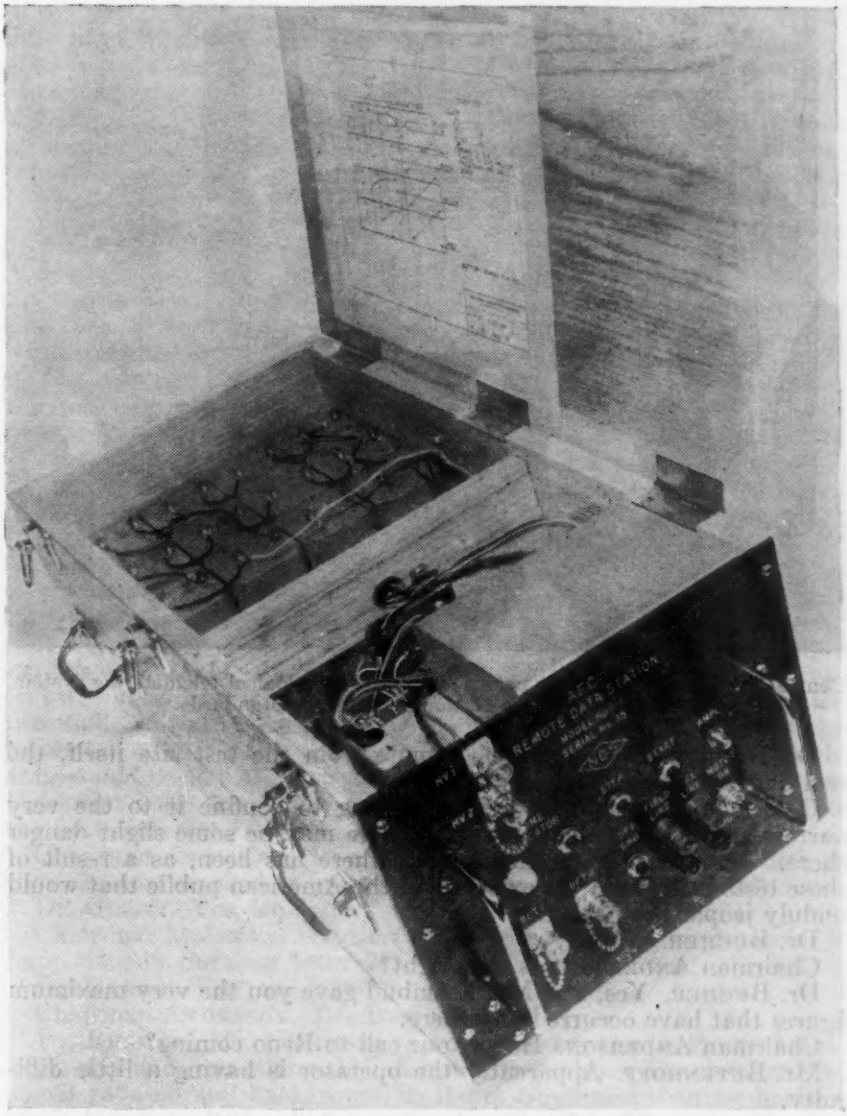
Chairman ANDERSON. Some few days ago there was a story in the paper that there had been radioactive rain in New Orleans. Somebody worried that there might be so much radioactivity it might be harmful. You would have been able to find that out, if there had been, would you not?

Dr. BUGHER. Yes, sir.

Chairman ANDERSON. And the fact there has not been a situation of that nature surely indicates that across the country as a whole there has been no danger of that nature from these tests?



View of radiological telemetering field station located at Reno, Nev., showing the radiation detector mounted at the standard 3-foot level.



Inside view of radiological telemetering field station, showing battery compartment, detector power supply, and electronics section.

Central control and recording console for AEC radiological telemetering system, developed by the National Bureau of Standards.

Dr. BUGHER. Once one gets remote from the test site itself, the real danger to people rapidly falls off.

Chairman ANDERSON. I am not trying to confine it to the very narrow area around the test site. There may be some slight danger there. But away from the test site there has been, as a result of these tests in Nevada, no exposure of the American public that would unduly jeopardize health?

Dr. BUGHER. No, sir.

Chairman ANDERSON. Is that right?

Dr. BUGHER. Yes, and Mr. Eisenbud gave you the very maximum figures that have occurred anywhere.

Chairman ANDERSON. How is our call to Reno coming?

Mr. BUTENHOFF. Apparently the operator is having a little difficulty.

Dr. BUGHER. May I take advantage of this little span of time, while we are waiting for this call, to complete the summary of this statement, then, Mr. Chairman?

Chairman ANDERSON. Yes.

Dr. BUGHER. Most of the problems associated with the development and testing of nuclear weapons are essentially quantitative. No statement as to effects of these tests on the people of the United States has any meaning unless it is based on the actual values of the fallout which has occurred. These values have been accurately determined and the most fundamental information has been published.

While no risk is ever absolutely zero, we are forced to conclude that deleterious effects from the existing levels of radioactivity on the

people of the United States, to the extent that they occur at all, are very, very small. Among the myriad other injurious factors of much greater somatic and genetic import, we see no possibility of recognizing any effect whatever on the general health.

Chairman ANDERSON. May I turn to Dr. Green for a question while we are waiting for this. You gave some evidences here of how these mutations occurred.

Dr. BUGHER. The call from Reno is coming through now.

Chairman ANDERSON. When will we have the result of the call to Reno?

Dr. BUGHER. We will have it in just a moment.

Chairman ANDERSON. Dr. Green, how many spontaneous mutations occur in man, if you can reduce it to figures at all?

Dr. GREEN. The estimates vary for different traits in man, but a figure of 1 in 100,000 to 1 in 1 million gene reproductions per generation may be taken as a reasonable figure. The figure I gave was about halfway between those two.

Chairman ANDERSON. Assuming a tenth of a roentgen exposure, which we have been talking about, would the increase be noticeable?

Dr. GREEN. It would be so small that it would take very refined techniques to detect it, techniques which are ordinarily available only in experimental animals.

Chairman ANDERSON. How much radiation would be necessary before the increase would be detectable, or at least noticeable?

Dr. GREEN. We have frequently spoken of the amount of radiation necessary to double the mutation rate. This is sometimes a convenient way of referring to the necessary radiation to increase the mutation rate sufficiently to be detectable. This amount of radiation has been estimated as surely less than 100 roentgens, 30 to 80 roentgens probably would do it. If you want a single figure, 50 roentgens might at this point be taken as the amount of radiation necessary to double the mutation rate.

Chairman ANDERSON. In other words, 300 to 800 times as much as they are now exposed to in order to double the mutation rate?

Dr. GREEN. Yes, sir.

Chairman ANDERSON. So that the possibility is pretty remote of it happening in the near future?

Dr. GREEN. Yes, sir.

Chairman ANDERSON. Dr. Bugher.

Dr. BUGHER. Mr. Chairman, I have the answer to the technical question, and something I did not know also. The background signal gave normal background in Reno, Nev., and then we heard a sudden shift in tone, which would indicate, if that was the detector, that appreciable radiation was being detected, whereas we know there is not anything in Reno. But Mr. Butenhoff just tells me he had instructed the people out there to tie to the detector end a source which would give one-quarter of a milliroentgen per hour, which is what the figures do show. I did not know that. I was disturbed for a moment on hearing that change of tone.

Chairman ANDERSON. You salted the mine a little bit. It was a very interesting demonstration.

Dr. BUGHER. The signal change which anyone in the room could hear amounts to a quarter of 1 milliroentgen per hour, somewhat less that the peak value which Mr. Eisenbud mentioned which has occurred in the East here.

Chairman ANDERSON. I want to thank you for bringing that large equipment here, Mr. Eisenbud, for letting us see it, because I think it furnishes visual proof of the fact that the Atomic Energy Commission is steadily concerned with trying to protect the public health. It is a very fine demonstration, I am sure.

What is the tolerance allowance in AEC plants?

Dr. BUGHER. The levels we use are those recommended by the National Committee on Radiation Protection, and the maximum permissible level is three-tenths of a roentgen, that is, 300 milliroentgens per week. We do not, however, in practice permit levels like that to be incurred, and actual plant operations go on normally at levels considerably less than that figure.

Chairman ANDERSON. It is possible for you to state what the AEC tolerance is for people in Western States adjacent to the test area?

Dr. BUGHER. Yes, sir. The criterion we have there is based on the consideration that the permissible exposure for the public generally—and this is accepted industrial medical practice—should be something less than what is considered a perfectly safe and workable industrial exposure. So that for the areas offsite we have been working on the criterion that people should not be subjected to more than 3.9 roentgens per year. Now that is one-fourth of the value which holds in atomic energy installations, and with the consideration that we do not have tests right along, the actual value tends to be even still less than the one-fourth.

Chairman ANDERSON. Do people who live at relatively high altitudes say, ten or twelve thousand feet, receive exposures higher than normal?

Dr. BUGHER. They receive higher exposures, Mr. Chairman, than those who live at low altitudes. They are all normal in that sense. The factors are something of this order: That from cosmic ray exposures, the rate from that doubles at about 5,000 feet, and at 10,000 feet it would, I believe, go up by another factor of 2.

Chairman ANDERSON. The purpose of that question was to ask, how does the exposure received by the people in the Eastern United States during the present test series compare with the exposure received by a person who may be living in Mexico City with an elevation of 7,500 feet?

Dr. BUGHER. I think I am correct in this figure—that it is appreciably less. That is, the exposure to people in the eastern part of the United States is appreciably less than that which will be incurred from natural sources at the altitude of Mexico City.

Chairman ANDERSON. That is what I wanted to get into the record, because people have worried that there may be excessive exposure in the eastern part of the United States as a result of these current tests. Now your testimony is that, if they moved to Mexico City and stayed there for a year, they would have had more exposure there than they got in the eastern part of the United States at sea level through this last year of tests?

Dr. BUGHER. The difference becomes very great as time goes on.

Chairman ANDERSON. Are there further questions by the members of Dr. Green, Mr. Eisenbud or Dr. Bugher?

Mr. Cole.

Representative COLE. I should like to ask Dr. Bugher to furnish for the record, when we reconvene this afternoon, a report showing

the amount of money that the Commission has paid for damages to property owners out in the test area, the continental United States, and, if possible, it could be broken down to damage caused by blast. I assume there may be no damage caused by light, but, if so, you could put that in, and the damage caused by fallout. If that could be given to us when we reconvene, it would show in some degree the amount of damage that these series of tests that have been carried on the last few years have caused our people.

Mr. STRAUSS. There may be some claims, Mr. Cole, that are not yet settled, but the figures we will give you will be those which have been.

Representative COLE. I was going to ask also—you know we changed the law last year making it possible for you to settle claims under $5,000. Would you tell us also if there are any outstanding claims or any claims which have been settled which have exceeded $5,000 and have that for the record?

Mr. STRAUSS. Yes.

(The information referred to follows:)

CLAIMS ARISING FROM NEVADA TEST ACTIVITIES

I. Claims received by AEC from beginning of Nevada tests up to current test series (February 1955)

Five hundred and seventy-one claims have been received by AEC from the beginning of the Nevada tests in 1951 up to the beginning of the current test series in February 1955. Three hundred and ninety-three of these claims were paid by AEC. The total amount paid was $52,159.34.

Of the claims received, two were from nearby mineowners who alleged that they were required to shut down their mines for a period of time as a result of radioactive fallout. One of these claims was settled for $1,000 and the other was denied.

Two claims alleged personal injury caused by radioactive fallout. These claims were both settled for $527.60 and $389.56, respectively. These claimants were paid only for out-of-pocket costs reasonably incurred by them for transportation, medical examinations, and the like. None of the payments made to them was for any personal injury, either caused by radioactive fallout or otherwise.

Seven claims alleged injury to horses caused by radioactive fallout. These were all settled for a total amount of $5,900.

The remaining 383 claims which we paid during this period involved minor blast damage to property in the aggregate amount of $44,342.18.

II. Suits pending against the Government in connection with Nevada tests up to current test series (February 1955)

Three suits have been filed against the Government alleging personal injury caused by radioactive fallout. Two of these suits are for $100,000 each, plus medical and hospital expenses and the third is for $75,000 plus medical and hospital expenses. The Government is denying liability and the suits are being defended by the Department of Justice. The Commission's medical experts are of the opinion, based on the actual exposures to external gamma radiation which these persons alleged they incurred, that none of their alleged symptoms could have been the result of exposures to the fallout radiation.

Seven suits have been filed against the Government alleging injury to sheep caused by radioactive fallout. These suits are in the aggregate amount of approximately $216,000. The Government is denying liability and the suits are being defended by the Department of Justice.

One suit has been filed against the Government alleging that radioactive fallout from Nevada tests, as well as activities of the Air Force at the Las Vegas bombing and gunnery range, amount to a taking of the plaintiff's mining property without due process of law. This suit is under the Tucker Act and is for $450,000. The Department of Justice has not yet filed its answer to this suit.

The final suit now pending against the Government is based on alleged structural damage caused by blast and is for $5,000. The Government is denying liability and the suit is being defended by the Department of Justice.

III. Claims received by AEC since commencement of current test series

Two claims have been received alleging injury to livestock caused by radioactive fallout. One is for more than $11,000; the amount of the other claim is not yet known. Although these two claims have been received during the current series, it is not yet clear whether the claimants are alleging that the injury to their livestock was caused by radioactive fallout from the current series.

One claim has been received from an individual alleging that, while driving his automobile, he was temporarily blinded by the flash of a shot with the result that he drove his automobile off the road. He is seeking $250 for damage to the automobile and $100 for medical expenses.

Seventeen other claims have been received alleging minor damage to property caused by blast.

Representative COLE. My only other inquiry was of Dr. Green. I was impressed by his statement that all mutations caused by irradiation have been deleterious mutations. By that I judge you mean, Dr. Green, that they are not good, not desirable mutations?

Dr. GREEN. Yes, sir. The statement was that they are usually deleterious.

Representative COLE. Yes.

Dr. GREEN. There is evidence from animal and plant experimentation that a low percentage of mutations may fall in the category we would call beneficial and may be used as a basis of crop improvement, induction of disease resistance in plants. But in the smaller experimental animals, and very likely also in man, the larger question is going to be to deal with the rather high proportion of deleterious mutations.

Representative COLE. Can you explain that in a sentence or two in a way that a layman can grasp why it is that mutations caused by irradiation are more likely to be deleterious than beneficial?

Dr. GREEN. The present living forms are a product of many, many years of evolution. They may be regarded as comprised of genes that have survived in natural selection over these many years. Any external force that acts upon this highly adjusted mechanism, may be expected to damage it rather than improve it.

Representative COLE. I judge by that, then, you conclude that man has improved himself, he has gone just as far as he can go, and any changes that may occur from here on are bound to be deleterious.

Dr. GREEN. This would be very difficult to speculate on, and I would rather not.

Chairman ANDERSON. Mr. Price.

Representative PRICE. No questions.

Chairman ANDERSON. Mr. Hinshaw, do you have any questions?

Representative HINSHAW. Yes, Mr. Chairman.

Reference has been made frequently in the course of this hearing to the radioactivity of the natural environment. I would assume that that radioactivity is both terrestial and cosmic. What is that amount of radioactivity in the terms of milliroentgens or roentgens, and what is the relationship between a millicurie and a milliroentgen?

Dr. LIBBY. I will attempt to answer your question, Mr. Hinshaw.

The natural background consists of several different sources of radiations. The body has in it the element potassium, and all potassium has a slight degree of radioactivity. That is one potassium isotope has a half-life of about 1 billion years.

Representative HINSHAW. Did you say 1 billion?

Dr. LIBBY. Yes. So about 35 milliroentgens per year, if my calculations are right—I have been calculating recently on the question

you ask—about 35 milliroentgens per year are received from the potassium alone in the body.

The uranium and thorium and potassium which occur in the earth's crust have additional amounts of radioactivity. This, of course, depends upon the nature of the soil. If you take a granite rock—if I remember the numbers correctly—the thorium in the granite rock will expose a person who is not shielded in any way, who is walking around on the surface of the granite rock, to about 40 milliroentgens per year, or slightly more than the body potassium.

The uranium in the granite rock and the radium that Mr. Eisenbud mentioned adds about 20 milliroentgens, and the potassium another 40.

Then, on top of this, the cosmic rays which reach to the sea level despite the great thickness of the atmosphere—they are very energetic and do reach to sea level—the cosmic rays add another contribution which, I believe, is in the order of 35 milliroentgens per year.

It is very interesting to know that the cosmic rays vary strongly with altitude, and at an altitude—if I remember the numbers correctly—at the altitude of Denver the factor of increase is such that the total background radiation would be much increased. In other words, rising from a total at sea level of the order of 170 milliroentgens per year on the granite rock assumption, at the level of Denver, something over 200 milliroentgens per year would be the natural background, the increase being due entirely to cosmic rays.

Typical background radiation on granite rock

[In milliroentgens]

	Sea level	5,000 feet elevation
Potassium in the body	35	35
Thorium in granite	40	40
Uranium and radium in granite	20	20
Potassium in granite	40	40
Cosmic rays	35	65
Total	170	200

We have, in addition, the fact that even though granite is the hottest rock, so to speak, nothing is very cool. The most favorable soils run about a quarter of granite. So even with these the intensity of background radiation is very considerable, and, of course, the cosmic rays are not affected by this.

The sea and the rivers are lower in background contamination than the soils. So the background exposure of sailors is much lower than that of people living on the land.

There are endless variations of this background question, but I think I have mentioned the principal contributing factors of any importance.

Representative HINSHAW. You speak of background radiation as being the radiation of the natural environment?

Dr. LIBBY. Yes.

Representative HINSHAW. And I believe, if one adds up your first set of figures, he comes to approximately 170 milliroentgens for the

normal radiation background of the natural environment that goes on all the time at around sea level or, say, the level of Washington.

Dr. LIBBY. That is right.

Representative HINSHAW. And then you say on the order of 200 milliroentgens at the elevation of Denver, which is 5,000 feet, approximately?

Dr. LIBBY. That is right.

Representative HINSHAW. And that goes on all the time, and has gone on since time immemorial, and will. It was increased in early times by the fact that less decay had taken place at that time. Is that correct?

Dr. LIBBY. Yes.

Representative HINSHAW. Then I would assume from your statement and that of Dr. Green that the mutations in the species have been due to this normal background radiation over the ages. Is that true?

Dr. GREEN. And other factors.

Dr. LIBBY. There are probably other factors which cause mutation, I believe, in addition to radiation. Chemical agents can cause mutation.

Representative HINSHAW. But the mutations incurred by radiation have been going on for millions and millions of years due to this same radiation background that we speak of; is that right?

Dr. LIBBY. Yes, sir. I think that is correct.

Representative HINSHAW. And I believe you say in the course of your statement that there has been an increase of maybe a tenth of 1 percent in the general radiation background due to fallout from the 40 or so atomic tests that have already taken place?

Dr. LIBBY. A very small fraction. The increase is a very small fraction of the background.

Representative HINSHAW. Very small. That is in the nature of a tenth of 1 percent or less?

Dr. LIBBY. I am not prepared to attest to the exact number. Is that correct, Mr. Eisenbud?

Mr. EISENBUD. As far as I know, except for the immediate region of the Nevada test site, this increase is not demonstrable by normal instrumental procedures.

Representative HINSHAW. And there is enough difference from place to place so that it would be almost undetectable?

Dr. LIBBY. Yes, sir.

Mr. EISENBUD. And from hour to hour.

Representative HINSHAW. That is correct; is it not?

Dr. LIBBY. Yes, sir. The variations from one locality on the earth to another are much larger than the total intensity of our fallout.

Representative HINSHAW. I think that explains a great deal, Mr. Chairman. We have been having radiation for millions of years, and the amount of increased radiation due to the atomic tests is almost undetectable.

Chairman ANDERSON. I think that is very important in the discussion that the people constantly have this fact in mind.

I would like to return, Mr. Chairman, to your statement where you mention the fact that the Bikini device produced a radioactive fallout over an area of several thousand square miles. And the figure, I believe, was given once of something like 7,000 square miles. Is that

tied in any way to the discussion we have been having here of normal radioactive exposures from these tests at Las Vegas?

Mr. STRAUSS. No, Mr. Chairman, and I am very happy that you have asked the question. The point I was trying to make in my statement, and perhaps failed to make, was that there has been a confusion between the results of the high-yield thermonuclear tests in the Pacific and the quite low-yield devices that are tested at the Nevada proving grounds.

Chairman ANDERSON. That is what I am trying to make clear also. I would not want someone to leave here with the impression that if a small device is tested at Las Vegas, there can be fallout in a cigar shaped pattern over 7,000 square miles.

Mr. STRAUSS. It would take many thousands, several thousands, of such devices as have been tested in Nevada to equal the energy release and fallout that occurred in Bikini.

With your permission, Mr. Chairman, I would also like to take advantage of the fact that Dr. Bugher is here—almost in spite of the fact he is here—since he is going to return within a matter of months to the Rockefeller Foundation, from which institution he has been on leave to the Commission, to say that he is responsible for the origination of this monitoring system. It has been of great value and will probably in the course of years be of enormous value to the country. I would like on behalf of the Commission to pay a tribute of acknowledgment and gratitude to him.

Chairman ANDERSON. Mr. Cole.

Representative COLE. Mr. Chairman, I just want to clarify what I think is a misunderstanding I have had with respect to Dr. Green's statement to the effect that mutations caused by irradiation are deleterious. Is that peculiar only to the mutations caused by irradiation, or may that also be said with respect to mutations irrespective of cause? Or is it more likely that the mutations would be deleterious than beneficial?

Dr. GREEN. New mutations, no matter from what source, may be largely, usually are, deleterious.

Representative COLE. Thank you very much. I find that I did misunderstand your statement. I thought you emphasized deleterious effect from irradiation because of the peculiarities of irradiation itself.

Before we release Dr. Bugher, on the question of strontium 90, may I inquire if that is a product of the atomic age?

Dr. BUGHER. Yes, Mr. Cole; it is entirely a product of the atomic age.

Representative COLE. And you estimate that strontium 90 now in existence is about one-thousandth of a dangerous proportion?

Dr. BUGHER. It is less than that on the average, but the very maximum we have been able to find is less than one-thousandth.

Representative COLE. Does that mean that if atomic tests and explosions continue at the rate that they have in the last few years since the atomic age, that civilization can feel secure for approximately a thousand years? Is that not a reasonable assumption?

Dr. BUGHER. It is very reasonable, Mr. Cole. The point is that this material also decays in time, so that what actually develops is an equilibrium. It does not continue to accumulate indefinitely. There would be no prospect any time whatever of the amount of strontium 90 reaching a level which is much more than it is right now,

even though tests were to continue uniformly indefinitely in the future.

Representative COLE. That is a very, very comforting statement to hear, if I understand correctly what you have said. Would that same statement be true if atomic explosions were accelerated many, many, many times over what have occurred in the last 5 years?

Dr. BUGHER. If we have a very large acceleration of rate, then there would be a gradual buildup to a new equilibrium level, which would be appreciably above what it is now or what it will be, but it would take a very large number to bring an equilibrium level of strontium 90 up to a point where we would have reason to expect to actually be damaging.

Representative COLE. Is there any reason for civilization to be concerned with respect to damage, harm, because of strontium 90?

Dr. BUGHER. It depends on the meaning of "concern," Mr. Cole. From the scientific standpoint we naturally want to know as much as we can, and the scientist, therefore, is concerned because he feels that we should have complete measurement of all of these factors.

I have estimated that the equilibrium level of strontium 90 would have to be raised between 100,000 and a million times over what it is now before we could expect to detect any change in human pathology and disease due to the isotope.

Representative COLE. Dr. Libby.

Dr. LIBBY. I think it might be interesting to add—I am sure Dr. Bugher did not mean to omit it—that the strontium 90 has no genetic effect.

Dr. BUGHER. That is right.

Dr. LIBBY. It goes to the bones, you see, which have no genetic significance. I thought maybe the record might be clearer if that statement were in there.

Dr. BUGHER. Thank you.

Representative COLE. Just to take a minute more to get an understanding of what you mean when you say strontium 90 will build up an equilibrium, does that mean a degree of tolerance to the human system? Or what do you mean by an equilibrium?

Dr. BUGHER. No, sir. It derives from the physical situation. You are getting a steady increase, but the material that is formed itself continues spontaneously to decay or decrease.

Representative COLE. But you have indicated strontium 90 has a very long half-life.

Dr. BUGHER. 20 years.

Representative COLE. Only 20 years?

Dr. BUGHER. Yes. So that in the terms of centuries and so on, this is a very short time, of course. In the lifetime of an individual it is important as a period of decay.

Representative COLE. At any rate, as one charged with the responsibility of the health and safety of the American people and civilization generally, are you seriously disturbed by the hazard of strontium 90?

Dr. BUGHER. No, sir; not actually.

Representative COLE. Thank you.

Chairman ANDERSON. I know, Mr. Chairman, that many people would like to have you say whether or not there is any way that we can minimize this fallout danger in case of enemy attack. While that

really is not part of this hearing, and it may be a civil defense answer, would you want to comment at all on this area in which you have mentioned in your statement there would be exposure to serious fallout? Is there anything that may be done to minimize it? Is it a hopeless danger that confronts us?

Mr. STRAUSS. Mr. Chairman, there was a session of one of your subcommittees, I think, about 10 days or 2 weeks ago, at which the subject was covered at length by Commission witnesses and the Federal Civil Defense Administration. I would feel incompetent, without some preparation, to put into this record a comprehensive answer. It is certainly not hopeless. There is a good deal of promising experimental work in progress in the Commission's laboratories looking toward protection of cell structures against radiation. I would not want to say anything that would be stimulative of undue optimism, unbridled optimism, but it is not a hopeless situation at all.

Chairman ANDERSON. What I was trying to get to, Mr. Chairman, was this: The detection device over there shows how carefully we are trying to check the most minute particles or contamination, and that is a protective and helpful device to all humanity. At the same time, does the Atomic Energy Commission not have in progress large-scale protection as well, that it is trying to think about always?

Mr. STRAUSS. Yes.

Chairman ANDERSON. The dangers that come from a bombing are not forever out of your mind; are they?

Mr. STRAUSS. Not at all. There is a division, as you know, charged with that responsibility, with an advisory committee of the best, most competent medical and radiological authorities that we can find in the country, at work on it. They are shortly to meet. I believe next week. They meet periodically about once every 2 months.

Chairman ANDERSON. I wanted that assurance.

I know Dr. von Neumann has an appointment this afternoon, and we are about to adjourn. I wonder if you might just put into the record in a few sentences, or as much space as you wish to take, any comments you may wish to make on long-range effects on weather of atomic energy explosions and nuclear detonations generally. Will it affect our weather very materially? Or will it take a very substantial amount to affect our weather?

STATEMENT OF DR. JOHN VON NEUMANN, COMMISSIONER, ATOMIC ENERGY COMMISSION

Dr. VON NEUMANN. It will probably take a great deal more than what has happened so far. Dr. Wexler discussed a number of rather delicate and more or less localized, or, anyway, limited-area effects which might exist in connection with nucleation, with rain and so on.

There is an overall effect, which is the raising of dust in general.

The energy involved in an atomic bomb is large by ordinary concepts, but not very large from the point of energies involved in climate and meteorology. I think 1 inch of rain over the State of Pennsylvania corresponds to 2,000 megatons.

However, what is a very great effect is if you put a pall of dust over the earth, it excludes sunlight and thereby has essentially cooling effect. This is a known phenomena.

A large volcano, Krakatoa, erupted in the 19th century. Krakatoa reduced the solar heating of the earth by something between 5 and 10 percent over 3 years. It has been calculated that one eruption like this every year would be enough to bring back the conditions of the last ice age. We have reason to believe that the amount of material thrown up by Krakatoa was about 100 times that of the largest nuclear explosion so far. This means that on the scale of the way things are going now it is not at all likely that there should be any large-scale effect of this kind. It is true, however, that if one wanted systematically to affect the climate, one could explode large nuclear bombs in a different way—underground—and this would have a much larger effect. But this is not the way it is done. Therefore, at this moment large-scale climatic effect is not present.

Chairman ANDERSON. Mr. Cole.

Representative COLE. How many Krakatoas did you say would bring about the ice age?

Dr. VON NEUMANN. Usually it is believed about one a year.

Representative COLE. One a year?

Dr. VON NEUMANN. Yes; it would take a little while.

Representative COLE. If the time ever should come that there would be nuclear or thermonuclear explosions to the point of a hundred a year, then in time we could anticipate the ice age?

Dr. VON NEUMANN. We would notice real climatic changes after 10 or 20 years of that. But, of course, there are other effects you would notice a great deal, long before that time.

Chairman ANDERSON. At least it has not done it as yet.

If there are no further questions, I think we had better adjourn now.

Mr. Chairman, would 2:30 be a convenient hour?

Mr. STRAUSS. Any time you set, sir. I would ask if I might be absent until 3 o'clock, but the other members will be here.

Chairman ANDERSON. We will reconvene at 2:30 to hear Dr. Wexler. Dr. von Neumann, you can go on with your appointment, and, Admiral Strauss, we will not expect you until 3 o'clock.

(Whereupon, at 1:10 p. m., the Joint Committee recessed to reconvene at 2:30 p. m., of the same day.)

AFTERNOON SESSION

Chairman ANDERSON. We will resume again at this time.

We will proceed now from witnesses of the Atomic Energy Commission and ask Dr. Harry Wexler, of the Weather Bureau, to give us his comments on the effects on weather.

Thank you Doctor, for being here.

STATEMENT OF DR. HARRY WEXLER, CHIEF, SCIENTIFIC SERVICES DIVISION, ACCOMPANIED BY DR. LESTER MACHTA, CHIEF SPECIAL PROJECTS SECTION, UNITED STATES WEATHER BUREAU, WASHINGTON, D. C.

Dr. WEXLER. Thank you, Mr. Chairman.

May I first express the regrets of Dr. Reichelderfer, Chief of the Weather Bureau, that he cannot be present at this important hearing. He is presently officiating as President of the United Nations World

Meteorological Organization at its second Congress in Geneva, Switzerland.

There is a natural human tendency to associate two events occurring close together as cause and effect. This holds in many fields, but is particularly prevalent in weather. From time immemorial man has been exposed to the vagaries of weather and in attempting to explain these has pointed the finger at many factors—astronomical configurations, plant, animal and insect manifestations, and in more recent centuries, at his own technological innovations.

Successively, with the appearance of gunpowder, steam and gasoline engines, radio communication, the airplane, and now nuclear energy, man has thus attempted to explain the vicissitudes of weather to which he is exposed. The interesting feature of this historical process is that the variety of weather changes is equaled only by man's inventiveness in trying to explain them.

The advent of nuclear energy has convinced many people that here at last is a source of energy large enough to influence the weather. Probably part of this belief stems from the familiar mushroom cloud of an atomic explosion which to the untrained eye is similar to the well-known thunderstorm cloud. From this superficial similarity it is a small step to attribute to nuclear explosions any unusual weather occurring in the individual's neighborhood. So a nuclear explosion is blamed simultaneously for heavy rains or drought, cold weather or hot weather, stormy weather or lack of wind.

A few years ago the changing complexion of letters received at the Weather Bureau indicated a growing popular interest in atom bombs and possible weather effects. Accordingly, a study was initiated to poll the leading meteorologists about possible connections and to study the weather records for many years to see if weather occurring since the beginning of the atomic age differed significantly from that before 1945.

Here I would like to add that in its study the Weather Bureau has received the wholehearted cooperation of the Atomic Energy Commission in obtaining the necessary facts.

Suggested influences of nuclear explosions on weather: Of the 80 or so replies received from these inquiries, about half indicated that the writers could see no possible connection between the atomic explosions and the ensuing weather. The others speculated that if there would be any connection at all, it would be along these lines: The atomic debris might serve as a cloud seeding agent; that the radioactive nature of the debris might produce changes in the electric parameters of the atmosphere, and that these, in turn, might produce some changes in the more directly observable weather elements; or that the dust resulting from an atomic explosion might interfere with the amount of solar radiation reaching the earth. None of those who replied believed that the energy of the atomic bombs exploded in Nevada could have any direct effect on the weather beyond the proving ground, and several volunteered arguments against this possibility.

Each of the possibilities listed above was investigated and the results published in Science, the official organ of the American Association for the Advancement of Science, in the January 21, 1955, issue. A brief summary is given here.

Cloud seeding: It has been established that in those portions of the atmosphere containing condensed moisture but a deficiency of ice-forming nuclei, one can actually alter the physical characteristics of certain types of clouds mainly by changing them to ice crystals. It appears that over 99 percent of the Nevada dust which is raised by the atomic explosions represents desert soil in an unaltered state.

Analysis of this soil by the Air Force Cambridge Research Center and Dr. Vincent Schaefer of the Munitalp Foundation, reveals that the Nevada dust has very poor ice-nucleating properties. The Air Force tests further indicated that the ionizing properties of the radioactive debris appear to play no role in the precipitation formation in their laboratory. That laboratory is also attempting to determine the nucleating properties of the coral dust raised during the Pacific tests.

Electrical properties: The electrical conductivity of the atmosphere is altered locally when the radioactive debris is deposited on the ground as fallout or when the cloud passes overhead. The ionizing radiations from the deposited debris change the conductivity in such a shallow layer near the ground as to be insignificant when viewed in terms of usual atmospheric phenomena.

The passage of the atomic cloud overhead, by increasing the electrical conductivity of the air, may interfere with the charge separation mechanism in thunderstorms in such a way as to inhibit lightning strokes. We have not found any evidence to show that this has ever occurred. We feel that the presence of atomic debris while giving rise to detectable changes in local electrical fields plays no significant role in the weather.

Solar radiation: In 1883, the catastrophic eruption of a single volcano, Krakatoa, increased the dust in the atmosphere sufficiently to cause a 10-percent decrease in the intensity of solar radiation as far away as France for a period of 3 years. Whether or not the Krakatoa explosion and dust had any effect on world weather has not been determined. Nothing like the Krakatoa dust pall has been observed since, either from volcanoes or nuclear explosions in Nevada or in the Pacific.

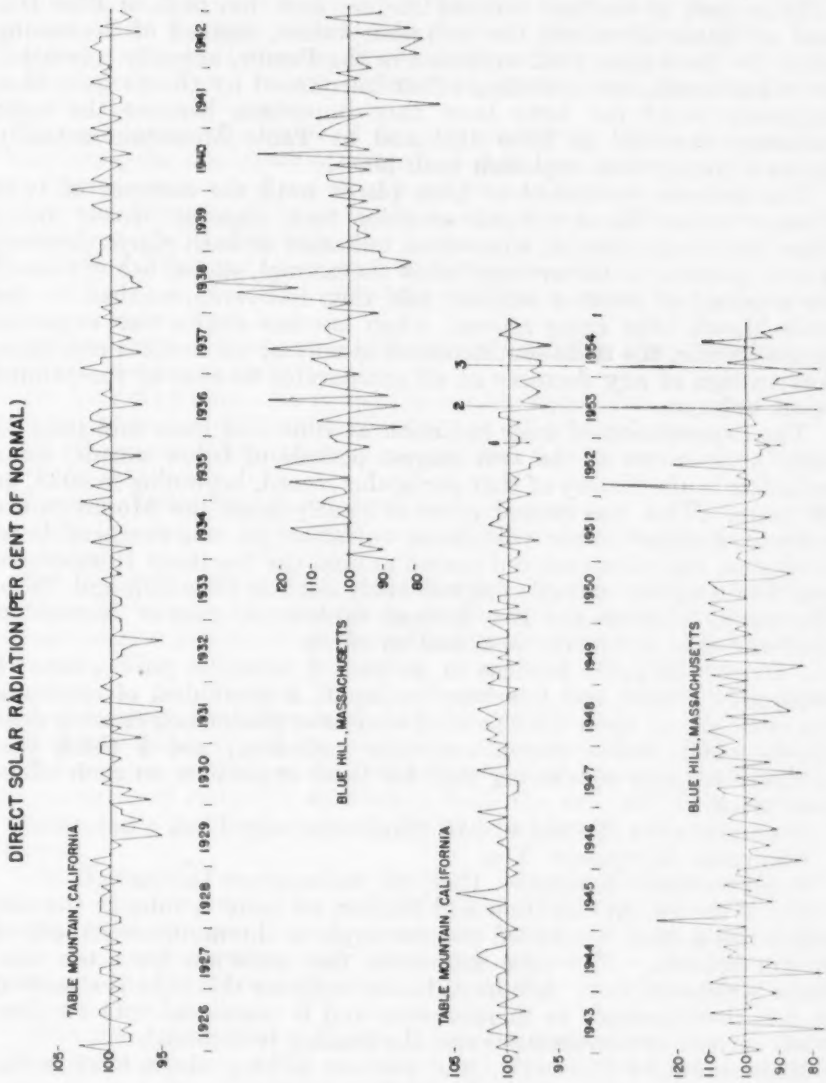
I would like to digress from my text and show a chart giving the solar radiation in relation to the tests.

(The chart referred to appears on the opposite page.)

Representative HINSHAW. Is that reproduced in the pamphlet entitled Effects of Atomic Explosion?

Dr. WEXLER. No, sir. We can reproduce them in the record of this hearing if so desired. These curves refer to solar radiation intensities made at two observatories in the United States, one at Table Mountain, Calif., run by the Smithsonian Institution, and the other at Blue Hill, Mass., run by Harvard University.

The radiation measurements are made by pointing an instrument at the sun and taking a direct measurement. In Table Mountain the observations began in 1926 and at the Blue Hill Observatory, in 1933. The data are plotted with reference to the normal, which is the horizontal line, labeled "100 percent," and there are up and down variations in radiation both at Table Mountain and at Blue Hill. The early part of the record is on top. The latter part of the record is at the bottom.


DIRECT SOLAR RADIATION (PER CENT OF NORMAL)
TABLE MOUNTAIN, CALIFORNIA
105
100
95
1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942
BLUE HILL, MASSACHUSETTS
120
110
100
90
80
TABLE MOUNTAIN, CALIFORNIA
105
100
95
1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954
1
2
3
BLUE HILL, MASSACHUSETTS
120
110
100
90
80

These vertical lines here may not be too easily discernible. The first vertical line (1) refers to the thermonuclear device exploded in the Pacific in November 1952. The second vertical line (2) in July 1953 refers to a rather minor volcano that occurred at Mount Spurr near Anchorage, Alaska. The third vertical line (3) is March 1, 1954, when the second device was exploded in the Pacific.

If we look at the first vertical line, we find that both at Blue Hill and at Table Mountain the radiation values, instead of decreasing after the November 1952 explosion in the Pacific, actually increased. In other words, any screening effect introduced by clouds from that explosion could not have been very important because the solar radiation received at Blue Hill and at Table Mountain actually increased after that explosion took place.

The increase continued at both places until the summer of 1953 when a rather minor volcanic eruption took place at Mount Spurr near Anchorage, Alaska, whereupon radiation at both places dropped 5 to 10 percent on the average below the normal, stayed below normal for a period of about 6 months, and then recovered, so that by the time March 1954 came around, when another device was exploded in the Pacific, the radiation increased to normal values; in short there was no sign of any decrease at all comparable to that of the Mount Spurr volcano.

The depreciation of solar radiation at Blue Hill from mid-1953 to early 1954 is one of the two longest periods of below normal solar radiation in the history of that particular record, beginning in 1933, or 20 years. This was caused quite evidently from the Mount Spurr volcano, a rather minor volcano as volcanoes go, not comparable to Krakatoa, but whose ash did spread around the Northern Hemisphere and decreased the radiation significantly both at Blue Hill and Table Mountain, whereas the two nuclear explosions, that of November 1952 and that of March 1954, had no effect.

I stress this point because in at least 2 scientific publications, 1 written in France and 1 written in Japan, a great deal of emphasis has been placed upon the effects of nuclear explosions on causing dust clouds which would screen out solar radiation; and I think this evidence is quite convincing that for these explosions no such effect took place.

Representative HINSHAW. Mr. Chairman, may I ask a question?

Chairman ANDERSON. Yes.

Representative HINSHAW. How do you measure this radiation?

Dr. WEXLER. At the Blue Hill Station we point a tube at the sun which has a small blackened thermocouple or thermometer imbedded in the bottom. The tube intercepts the radiation from the sun. None is reflected out. All the radiation entering this tube is absorbed at this thermocouple or thermometer and is translated into an electrical current or temperature and the reading is obtained.

Representative HINSHAW. And you are talking about heat radiation and not light?

Dr. WEXLER. Both. This measures the whole spectrum of solar radiation reaching the bottom of the atmosphere.

Representative HINSHAW. You cannot measure light with a thermocouple.

Dr. WEXLER. Well, this particular receptor has a black body thermometer or thermocouple which absorbs all the radiation falling upon

it. This has been tested by the Smithsonian Institution and has been found to be practically 100 percent absorbent of all the light. The absorbed light and heat energy change the temperature and therefore the electrical current.

Representative HINSHAW. I would like to ask Dr. Libby to comment on that question.

Dr. LIBBY. I think the answer is that this black-body thermometer does measure the light as heat and converts the light into heat.

Representative HINSHAW. It converts the light into heat?

Dr. LIBBY. Yes. It is a measure of everything that comes from the sun, its total energy.

Representative HINSHAW. I am just wondering about this because there are quite a number of radiations that have come from the sun, as everyone knows, and not all of it is light and heat, as I understand it.

Dr. VON NEUMANN. In terms of energy, almost all that gets to the thermometer is visible light and ordinary heat, mainly visible light. This light falls on the body, and the body is black, and it is converted into ordinary heat. What gets through the atmosphere in terms of energy is visible light.

Representative HINSHAW. And you are talking about the energy that reaches the earth?

Dr. VON NEUMANN. It is mainly visible light, but as soon as it falls upon the body, it can swallow it, and it becomes heat.

Dr. WEXLER. The maximum energy that the sun sends out is found at the visible bands.

Representative HINSHAW. Is this curve corrected for these variations in the sun, as sun radiation itself, or is that considered to be a constant?

Dr. WEXLER. We really do not know exactly what the sun sends out because we cannot get outside the earth's atmosphere. Smithsonian measurements indicate that the solar constant varies by less than one percent. This radiation is subject to all sorts of depletion in the atmosphere, as indicated by the 10 percent and higher variations, caused by dust particles, water, and things like that.

Representative HINSHAW. However, there are places, like in Chile and elsewhere, stations of the United States that are measuring certain wavelengths of radiation that come from the sun, and they claim, I believe, that that radiation varies in accordance with the area of sunspot.

Dr. WEXLER. Yes, sir; that is true. The Smithsonian solar stations at Montezuma, Chile, and Table Mountain measure, in addition to the total radiation received at the bottom of the atmosphere, individual wavelengths, and when you get out to the ultraviolet portion of the spectrum there are rather large variations, depending on the state of the sun.

With greater sunspot activity, there is a greater amount of ultraviolet radiation sent down at times than there is with lesser sunspot activity, but the ultraviolet component of the solar radiation represents a very small percentage of the total energy of the solar radiation.

If I may proceed then, Mr. Chairman, assuming there are no further questions, I will resume my testimony and come back again later to talk about another chart on precipitation and drought.

To go on then with the possible effects of nuclear explosions on weather, there is the effect of the explosion itself to be considered.

None of the scientists who replied to the inquiry about A-bombs and weather felt that the energy of the explosion itself could have a significant effect on the weather.

Comparisons with natural phenomena suggest that the energy of an A-bomb, while tremendous compared with the energy of other man-made explosions, is relatively small compared with that of many natural phenomena. Even H-bombs, with energies several hundred times that of the nominal A-bomb, represent less than $\frac{1}{100}$ of 1 percent the energy of winds in the atmosphere.

So much for the various hypothetical suggestions given to us as a result of our poll.

Then there is another way of examining this question, and that is to compare the weather we have been having during the last few years with preatomic age weather.

It may be argued that the weather is being modified by the A-bomb tests in spite of our finding no theoretical reason for believing this to be the case. It is therefore necessary to inspect climatic records to detect any changes in the weather that may reasonably be connected with the Nevada bomb tests.

Tornadoes: The climatic element most often cited as having been changed by the atomic-testing program in the United States is the frequency of tornadoes. The number of tornadoes reported in 1953 (532) exceeded the previous highest annual total by more than 200. A careful examination of the system for reporting tornadoes reveals considerable improvement since 1950, with perhaps the greatest improvement taking place in 1953 and continuing into 1954; it is believed that much of the increase in tornado reports can be traced directly to these improvements in reporting.

A study of the relationship between areas of radioactive fallout, or the presence of atomic clouds, and tornado occurrences reveals that there were relatively fewer tornadoes reported in areas of the atomic clouds or areas of large radioactive fallout than in areas of relatively small fallout.

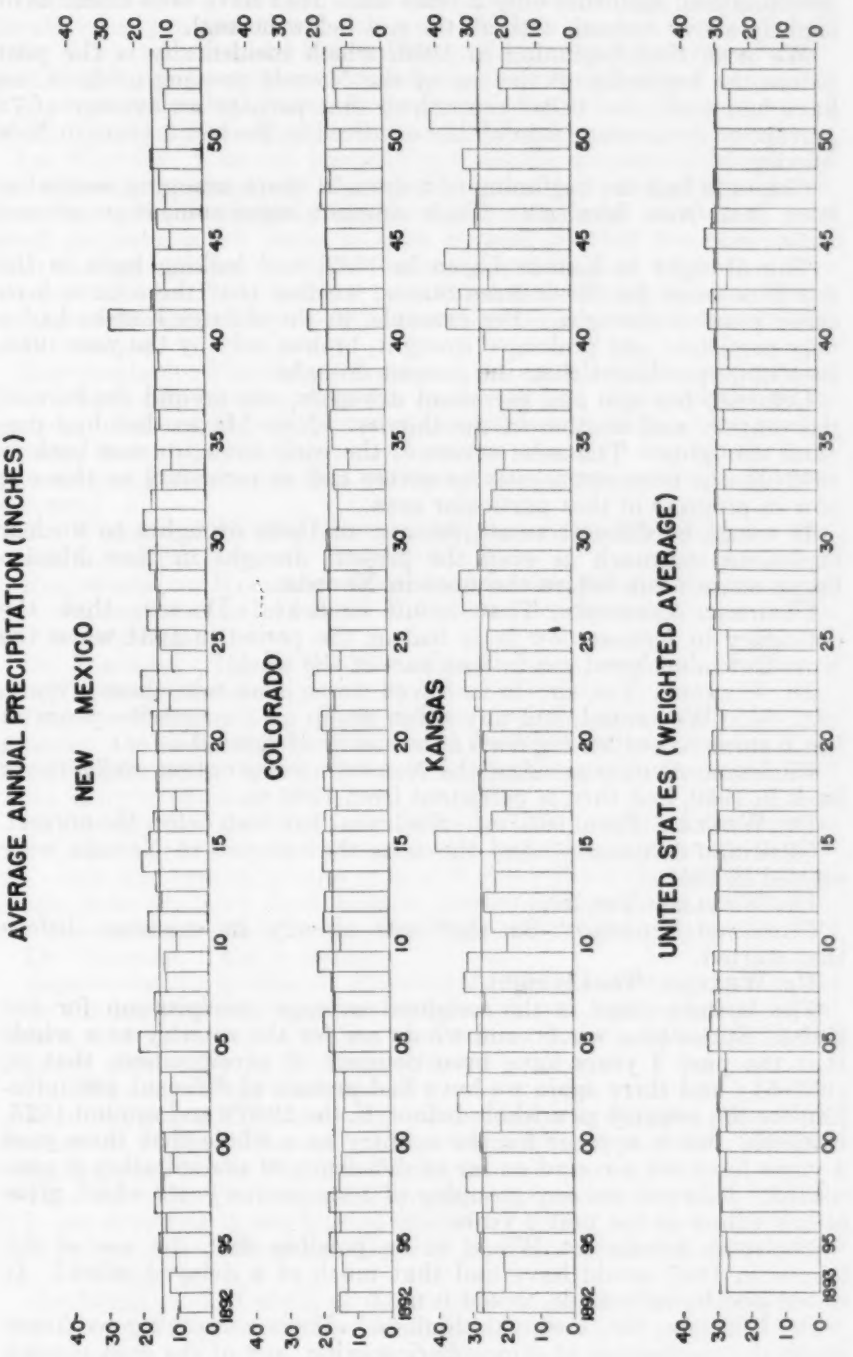
Finally, it is of interest to note that the current spring season so far has had about 50 percent fewer tornadoes than in 1953, although there were twice the number of atomic explosions in Nevada this year than up to the same date in 1953.

Precipitation: Parts of the United States have been experiencing a severe precipitation deficiency in the last few years. A drought, which began slowly in the late forties in the Southwest and more recently in the Plains States, is now acute in an area northward from New Mexico and Texas. We can illustrate the lack of rainfall in a few of the drought-stricken areas on chart II.

(The chart referred to appears on the opposite page.)

Here we have four rainfall charts beginning in 1892 for New Mexico, Colorado, Kansas, the heart of the drought area, and in 1893 for the United States average, showing year by year the actual precipitation in inches for each year. We note for New Mexico, that normally the average annual rainfall is something like 14 inches, as shown by the horizontal line, and we note the variability of the rainfall above and below that average.

For example, 1941 was an exceptionally good year. About twice the average amount of rainfall fell in that year, but beginning shortly thereafter in New Mexico there has been a persistent deficiency of


AVERAGE ANNUAL PRECIPITATION (INCHES)
NEW MEXICO
COLORADO
KANSAS
UNITED STATES (WEIGHTED AVERAGE)
1892
1893
95
00
05
10
15
20
25
30
35
40
45
50

precipitation, such that only 2 years since 1944 have been either at or slightly above normal, with all the rest below normal.

We note that beginning in 1950, which incidentally is the year before the beginning of the use of the Nevada proving grounds, we have had each year below normal, so that perhaps an average of 75 percent of the average rainfall has occurred in the last 5 years in New Mexico.

Colorado had the beginning of a drought there emerging somewhat later than New Mexico's. Their drought began somewhere around 1950.

The drought in Kansas began in 1952, and looking back in the previous years for these three States, we find that there have been other years of drought. For example, in the thirties Kansas had a very persistent and prolonged drought, broken only by the year 1935, even more persistent than the present drought.

Colorado has also had persistent droughts, one around the turn of the century and another in the thirties. New Mexico has had previous droughts. The most severe of the early droughts was back in 1892–94 but none apparently as severe and as persistent as this one now in progress in that particular area.

It would be difficult to ascribe any of these droughts to nuclear explosions inasmuch as even the present drought in New Mexico began some years before the tests in Nevada.

Chairman ANDERSON. That would indicate, Doctor, that the deficiency in Kansas now is as bad as the period in 1934 when the Dust Bowl developed out in that part of the world?

Dr. WEXLER. Yes, sir; in fact even worse if we take these 3 years, 1952–54. We cannot find any other group of 3 successive years in the Kansas record having such a deficiency of rainfall.

Chairman ANDERSON. And the New Mexico situation really starts back in 1940, and then is persistent from 1950 on.

Dr. WEXLER. From 1950 on. Each year has been below the normal.

Chairman ANDERSON. And the tests that started in Nevada were started in 1951.

Dr. WEXLER. Yes, sir.

Chairman ANDERSON. So that was already in existence before that started.

Dr. WEXLER. That is right.

The bottom chart is the weighted average precipitation for the United States as a whole, and we do see for the country as a whole that the past 3 years have been deficient in precipitation, that is, 1952–54; and there again we have had periods of deficient precipitation for the country as a whole before, in the 1930's and around 1925, 1893–95; but it appears for the country as a whole that these past 3 years have set a record as far as deficiency of precipitation is concerned. I do not see any grouping of 3 successive years which gives as low values as the past 3 years.

Chairman ANDERSON. Would it be possible that the use of the bombs in 1945 would have had that much of a delayed effect? It would just be impossible, would it not?

Dr. WEXLER. Sir, I should think so. From everything we know about the mechanism of atmospheric mixing, any of the dust thrown up by those bombs would have been dispersed in very minute quantities, even if it did have some unusual potentialities.

Representative HINSHAW. The dust itself thrown up by the bomb should cause precipitation?

Dr. WEXLER. Yes, sir; it should help if it is the right type of dust; that is, if it has properties of introducing ice crystals into a cloud.

Representative HINSHAW. Is there any quantity of dust that would inhibit the formation of precipitation from moisture-laden clouds?

Dr. WEXLER. I do not know of any specific amount although the use of too large quantities of dust might lead to overseeding; that is, to splitting the available moisture into a very large number of very small droplets, much more so than normal, so that the chances of their coming together would be decreased and the rain would therefore not be formed. This has been mentioned with regard to some of the commercial rainmaking operations, where overseeding is something to be avoided.

Representative HINSHAW. Perhaps I do not altogether understand this. However, I believe that the books tell you that over the water surfaces of the earth, which is something like four-fifths of the earth's surface, the sun expends the same amount of energy as over the land masses; and I think that that is about 1 horsepower per square yard, is it not?

Dr. WEXLER. The unit I know is in gram calories per square centimeter per minute.

Representative HINSHAW. It does not mean a thing to the rest of us. Can you confirm that? I think E. O. Lawrence figured it out one time for the committee.

Dr. WEXLER. This is the first time I have ever seen Professor von Neumann stumped.

Dr. VON NEUMANN. It is 2 calories per square centimeter per minute. On the square yard it would be 16,000 calories, which is 64. Yes; that is right. Since Professor Lawrence said it, we could have taken it for granted.

Representative HINSHAW. He figured it out roughly 1 horsepower per square yard; that is working on the ocean, taking moisture from the ocean and raising it up a mile or 2 miles above the surface of the ocean, from whence it is supposedly carried over the land and eventually precipitated either orographically or otherwise. Is that correct?

Dr. WEXLER. That is correct.

Representative HINSHAW. Presumably the moisture being raised from the ocean is just as much today as it was last year or the year before, and so it has to be dropped somewhere; but it is not being dropped apparently in the United States.

Dr. WEXLER. That is correct.

Representative HINSHAW. But it must be being dropped somewhere else in the world. The net result is that there is as much moisture being dropped in the world as there ever was on the average.

Dr. WEXLER. That is probably correct, and the question is, Why is it not dropping in the United States?

Representative HINSHAW. Because it does not always drop in the United States.

Dr. WEXLER. If I could elaborate on that, we not only need nuclei and moisture for rain, but we need storms to come by to lift the air up to cool it to the dew point and cause clouds and precipitation to form.

Weather patterns that we have been experiencing in the central part of the country have been such that the moisture-bearing winds and the number of storms and the lifting mechanisms necessary for precipitation have been deficient. I do not believe it is a deficiency of nuclei; I believe it is a deficiency of moist wind currents and the lifting mechanisms associated with storms.

Representative HINSHAW. Would you be willing to compare the energy that is dissipated through one ordinary springtime electrical storm and that which is dissipated by the explosion of one atomic bomb of the Nagasaki type, say?

Dr. WEXLER. I once had that figure on the tip of my tongue. It is about one nominal bomb.

Representative HINSHAW. I read in the magazine Science that the average thunderstorm was the equivalent of about 13 of the average atomic bombs.

Dr. WEXLER. Thunderstorms do differ in severity.

Representative HINSHAW. Yes, but an average thunderstorm is the equivalent in energy release of about 13 atomic bombs of the Nagasaki type.

Dr. WEXLER. Yes.

Representative HINSHAW. Therefore, the explosion of such a bomb in the United States would be like a small puff almost compared to the energy dissipated by one electrical storm.

Dr. WEXLER. That is correct.

Looking at it another way, the solar radiation normally falling on 2 square miles in the course of a day equals one Nagasaki type of bomb.

Representative HINSHAW. I think it is a good deal less than that.

Dr. WEXLER. You are probably correct.

Representative HINSHAW. I read the article in Science which gave it as about a half a square mile, that being 1½ million horsepower over 1 hour.

Dr. LIBBY. I think you were quoting Dr. Machta's article.

Representative HINSHAW. Maybe I was. I do not have the article before me.

Dr. WEXLER. I think you are correct again.

Representative HINSHAW. I see you have the article; would you read it?

Dr. WEXLER [reading]:

> The thermal energy from the sun falling on 1 square mile of Nevada ground during an average spring day supplies as much heat as two nominal bombs.

Representative HINSHAW. That is right. One half square mile per bomb.

Dr. WEXLER. Are there any other questions on this particular point?

Representative HINSHAW. I would like to ask how they come to reverse the name platinum and call it munitalp?

Dr. WEXLER. I wish I knew, but all meteorologists are glad of the fact that there is a Munitalp Foundation supporting basic meteorological research.

Representative HINSHAW. Has it anything to do with this platinum?

Dr. WEXLER. I believe the man who established this foundation made his fortune in platinum.

Precipitation in the northern part of the drought area has been near normal during the current test series but the southern portion is still suffering.

We do not know the ultimate cause of the persistent dry periods in certain localities. But it is known that the precipitation anomalies are part of a larger story, the broad wind patterns circling the globe. Accompanying the dryness over the central United States last summer, was an unusually wet area over England and Japan, for example. No acceptable theory has been offered to explain how the Nevada tests could have such a profound effect on the entire northern hemispheric circulation.

The graph at the bottom of chart II shows the annual changes in the average precipitation over the entire country. The same trend toward drier weather since 1950 is evidenced here, too. Again, on an annual basis, there have been some years with less precipitation than 1954, the driest since the Nevada test site began operating.

Conclusions: A number of suggested mechanisms by which atomic explosions might affect weather has been investigated and a study of climatological data has been made to determine whether any weather anomalies exist that might be associated with atomic explosions.

Although it is not possible to prove that atomic explosions have or have not influenced the weather, it is believed that this study has shown that such an effect is unlikely. The results of this study may be summarized as follows:

1. No theoretical reason has been found for believing that a nuclear explosion or its aftereffects could account for a significant change in the weather more than a few miles from the site of the explosion.

2. A study of the records of precipitation and severe storms, such as tornadoes, does not seem to indicate any departures from normal that are related to the atomic explosions in Nevada. In particular, the severe drought now affecting the Southwest States began before Nevada was first used as an atomic proving ground, on January 1951.

Senator HICKENLOOPER. Dr. Wexler, in your No. 1 you have used the statement twice, "No theoretical reason has been found for believing," and so forth.

I am probably being a little hypotechnical here on this matter, but I have been told that there is a certain type of structure or construction which theoretically cannot be built, but it is built and operated. You mean when you say, "no theoretical reason," there are no data developed which, in spite of theory, would reasonably indicate any such results?

Dr. WEXLER. The data part is covered in conclusion 2.

Senator HICKENLOOPER. Do they not claim that the bumblebee cannot fly, in theory?

Dr. WEXLER. But he does. What we meant by the theoretical reason is this: That there may be some hypothesis for a reasonable connection between explosions and weather for which no data are available for checking. We have examined these possibilities and have found from the standpoint of physics that they do not work.

We may be wrong. However, of those particular speculations that were made and which we could test with data we found out that the data did not support them.

After publishing these conclusions last January, no comment was received from the 40 or 50 meteorologists who speculated about

possible connections between nuclear explosions and weather. We, therefore, assume that these speculations have been laid to rest.

Before I finish my remarks, I would like to comment briefly on the value of atomic debris as a meteorological tracer.

The use of the atomic debris as a tracer is leading to valuable meteorological information. As a result of the Nevada tests, sufficient easily identifiable tracer material is introduced into the atmosphere to be followed across the country by sensitive instruments. With observations of this type, much has been learned of the paths of air masses and the rates of atmospheric mixing. From observations of rainout of radioactive debris, knowledge of the precipitation process will increase. Also the data are useful in predicting fallout patterns for civil-defense purposes, so that danger to civilian population in time of nuclear war may be minimized by directing the evacuation into areas not affected by wind transport of radioactivity.

That concludes my formal statement, Mr. Chairman.

Chairman ANDERSON. Is there another statement to be made by the Weather Bureau?

Dr. WEXLER. No, sir. This is the end of our formal statement, but we do have maps and other records of storms during the current spring in case there are any questions on that.

Chairman ANDERSON. As I gather from your statement, you fail to find anything in theory, and then when you check the facts you fail to find any facts to support the theory if there had been one, so you are reasonably well convinced that it has not been affecting the weather?

Dr. WEXLER. Yes, sir.

Chairman ANDERSON. You understand there are a great many people who have been disturbed by this period of drought that your chart clearly indicates exists. They naturally would like to find an explanation, and they would like to find a fall guy if they could possibly do so; and your conclusion is that it is just not there.

Dr. WEXLER. No, sir. We have not been able to find any sign of it.

Chairman ANDERSON. Thank you very much.

Are there questions?

Senator HICKENLOOPER. Just to amplify what the chairman said, I take it from the standpoint of the weather, you have investigated all theoretical suggestions of one kind or another which have any possible reasonableness and have failed to find any facts or failed to develop any information which would indicate that these explosions have any effect upon the weather. Is that correct?

Dr. WEXLER. Yes, sir; that is correct.

Senator HICKENLOOPER. In other words, you have left no stone unturned in your investigations of any phenomenon which may have been observed or suspected?

Dr. WEXLER. That is correct, and we hope if anybody else has any suggestion that they will not hesitate to write to us, and we will give it serious attention.

Senator HICKENLOOPER. That invitation is pretty broad, because every once in a while I get suggestions from people round about that can answer all the questions, but they do not always seem to be reasonable enough to send on.

Dr. WEXLER. We get quite a few letters of that type, too, sir.

Chairman ANDERSON. Dr. Wexler, when was it that the Weather Bureau and the Atomic Energy Commission started their studies to determine whether these nuclear tests had any effect on the weather? When did you start these studies?

Dr. WEXLER. This was about 2 years ago, Mr. Chairman.

Chairman ANDERSON. And have you any idea how much money has been spent on these tests?

Dr. WEXLER. About $19,000.

Chairman ANDERSON. And you plan to continue with this type of study?

Dr. WEXLER. Yes, sir; we do. The $19,000 I referred to applies only to the analysis of the data. Since 1952 the Division of Biology and Medicine of the Atomic Energy Commission has supported research by the Weather Bureau on this and related projects to the extent of approximately $100,000. This includes the studies on the forecasting and analysis of the travel of radioactive debris from the Nevada tests which are necessary to the study of atomic bombs and weather. We expect to continue with this as long as the tests continue.

Representative PRICE. I have one question prompted by the comments made by various Members of Congress. In the days before we were able to get release of this type of information there was some inference made that the Weather Bureau held back release of information pertaining to radioactivity sort of reluctantly because of the resistance of the Atomic Energy Commission. Was there any substance to such a report?

Dr. WEXLER. No, sir. No substance at all. We have been cooperating very fully with the Atomic Energy Commission in collecting radioactive observations for them by means of these trays that were shown earlier this morning and samples of precipitation. We have thrown our facilities entirely open to the AEC in this connection, and they analyze the data and make use of them.

Representative PRICE. There is full and harmonious cooperation then between the Commission and the Weather Bureau?

Dr. WEXLER. Yes, sir.

Representative PRICE. That is all I have, Mr. Chairman.

Chairman ANDERSON. We have no additional witnesses.

If there are additional points, Mr. Strauss, that you would like to have developed, we would be very happy to have them developed.

In general, I think the hearing has been worthwhile to the committee, and I hope to the country, in relieving some worries that many people had, and I am particularly pleased to have a statement from the Weather Bureau that I hope disposes of the question of the weather in the absence of some affirmative proof that someone would want to bring forward that we could then submit to the Weather Bureau for studies.

Mr. STRAUSS. Mr. Chairman, may I consult my colleagues?

Chairman ANDERSON. Yes, indeed.

In the meantime it has been suggested that the article Effect of Atomic Explosions on Weather, that appeared in Science might profitably be added to the record at this point. Would that meet your approval?

Dr. WEXLER. It certainly does, Mr. Chairman.

Chairman ANDERSON. Then let the record show that at this point we will insert into the final record the paper on the effect of atomic

explosions on weather which was in Science magazine, January 21, 1955.

(The article referred to follows:)

Effects of Atomic Explosions on Weather

(L. Machta and D. L. Harris, U. S. Weather Bureau, Washington 25, D. C.)

(Reprinted by permission of Science, January 21, 1955)

(Footnotes on p. 60.)

Every year since the explosion of the first atomic bomb, both the United States Weather Bureau and the Atomic Energy Commission have received many letters suggesting that atomic bombs should be used to dissipate hurricanes and tornadoes or otherwise improve undesirable weather. Since the atomic weapons testing program was enlarged in 1951, both agencies have also received complaints from many parts of the world blaming unpleasant weather on the atomic explosions.

Although a casual examination of much of the recent climatic data might appear to indicate that some of the recent anomalous weather has been associated with atomic explosions, a more careful examination of the data does not support the hypothesis that atomic explosions have changed the weather.

When the best available observational evidence and the most plausible theories are considered together, there appears to be no reason for believing that any past atomic explosion at the Nevada Proving Ground has had any significant effect on the weather more than a few miles from the test site.

Historical background.—Although witnesses to atomic explosions have sought to find ways in which the awesome events may have altered the weather, few cases have been found in which even local effects occurred. The heat from the fires set by the atomic bomb at Hiroshima produced numerous showers in the moist air overlying the city, and the base surge of the underwater Bikini shot also led to the formation of showers that lasted for 20 to 30 minutes. (1, 2.)

Most of the clouds from explosions in Nevada have been tracked for several hours by aircraft, but none of the pilots has reported any unusual weather developments during these operations. For greater distances, the atomic cloud has been followed across the United States by means of meteorologic trajectories (3), and even though there has been no attempt to make a detailed study of the weather in association with the atomic clouds and areas of radioactive fallout, it is believed that any marked relationship would have been detected.

These findings suggest that if the Nevada atomic tests had any effects on the weather, they were either very slight or very obscure. This article (4) describes a systematic study made possible in 1954 by the accumulation of additional data beyond that available to previous investigations.

Suggested relationships.—To make sure that no reasonable hypothesis concerning the effects of atomic explosions on weather would be overlooked, suggestions were solicited from most of the organizations in the United States that employ meteorologists. Of the 80 or so replies received from these inquiries, about half indicated that the writers could see no possible connection between the atomic explosions and the ensuing weather. The others suggested that the atomic debris might serve as a cloud seeding agent; that the radioactive nature of the debris might produce changes in the electric parameters of the atmosphere, and that this, in turn, might produce some changes in the more directly observable weather elements; or that the dust resulting from an atomic explosion might interfere with the amount of solar radiation reaching the earth. None of those who replied believed that the energy of the atomic bombs exploded in Nevada could have any direct effect on the weather beyond the proving ground, and several volunteered arguments against this possibility.

We cannot, with our present knowledge of meteorology, dismiss the remote possibility that the atmosphere is so unstable that some small impulse such as that given by an atomic explosion could produce a weather change that might otherwise never take place. However, there does not seem to be any reason why such modification would necessarily produce worse weather than might occur naturally. A consideration of the available theoretical and observational evidence indicates that the probability of any change is small.

Cloud seeding.—Condensation does not begin in completely clean air until the relative humidity is at least 500 percent. Ordinary air, however, contains myriads of tiny dust particles—condensation nuclei—around which most natural cloud droplets are formed. Some of the nuclei can become active at relative humidities as low as 80 percent, and other such as ions require humidities greatly in excess

of 100 percent. However, humidities in excess of 100 percent in the free air are rare. There are usually so many of these particles present and the available moisture is divided among so many droplets that none can grow large enough by the initial condensation process to fall as rain. But if water droplets and ice crystals are present in the same cloud, the ice particles will grow at the expense of the water droplets and become large enough to fall through the air. Additional growth will be realized by accretion of smaller droplets in the path of the falling drop. According to Houghton (5) the ice particle mechanism is necessary to the formation of most precipitation in middle and high latitudes. However the coagulation of cloud droplets is also important and in the tropics may be the most important process.

Cloud droplets do not freeze at the same temperature as a large volume of water. Liquid water droplets have been observed in the atmosphere at temperatures as low as about −40° F. and at still lower temperatures in the laboratory. However, some of the nuclei have the property of causing the cloud droplets to freeze only a few degrees below the freezing temperature of bulk water. These particles, called ice nuclei (6) are not always present everywhere in the atmosphere and it is conceivable that the atomic explosions may supply them in regions with a natural deficiency. This possibility has been investigated by correlating the presence of ice nuclei and radioactive debris during a period of atomic explosions and by testing the nucleating properties of the material thrown into the air by the explosion.

Simultaneous measurements of the atomic debris and ice nuclei content of the air made at Mount Washington, N. H., in 1952 are shown in figure 1. The method of counting ice nuclei has been described by Schaefer (7); the method of measuring radioactive fallout has been described by Eisenbud and Harley (8). The continuous curve denotes the amount of radioactivity in dust deposited on the ground during a 24-hour period beginning at 12:30 p. m., e. s. t. on the date shown. The open circles are values interpolated from surrounding stations when reports from Mount Washington are missing. The smaller dots, usually eight per day, indicate the number of ice nuclei per cubic meter of air (9). If the debris from atomic bombs furnish good ice nuclei, the ice nuclei count should always be high when the radioactive fallout count is high. It is easy to see that this is not the case.

The only debris added to the air by an atomic explosion high above the ground is the material contained in the bomb itself, and only a small fraction, if any, of this material is thought to be effective as ice nuclei. In the case of low-altitude explosions a much greater amount of debris is thrown into the atmosphere. From the Nevada tests it has been found that more than 99 percent of the debris from a typical low-altitude atomic explosion consists of soil particles sucked up by the rising cloud without becoming radioactive or having their physical and chemical properties significantly altered by the explosion. Samples of this dust have been sent to two laboratories to be tested as ice nuclei. The Air Force Cambridge Research Center reported their findings as negative and Vincent Schaefer of the Munitalp Foundation emphasized the point by stating that the dust recovered from one rather muddy rain in Schenectady, N. Y., was 5,000 times more effective than the dust from the Nevada Proving Ground.

The possibility that the radioactive nature of some of the debris might play a part in cloud seeding was also studied at the Air Force Cambridge Research Center, using laboratory sources of atomic radiations. None of the radioactive material tested was effective in promoting the formation of ice particles.

The amount of radioactivity deposited on the ground is much greater on days with precipitation than on days without precipitation when similar amounts of radioactive debris are aloft (3), and the precipitation is more radioactive when debris from atomic explosions is in the air than it is in the absence of such debris. However, it is well known that precipitation is effective in scavenging natural dust and smoke from the air. The available data indicate that most of the radioactive material in rainfall is collected by the scavenging process, and the presence of radioactive material in rain does not indicate that this material was instrumental in producing the rain.

Electric effects.—The radiations from the radioactive debris produced by an atomic explosion increase the ionization of the air. This should lead to an increase in the electric conductivity of the air and a decrease in the electric potential gradient of the atmosphere. A check of the records of atmospheric conductivity and potential gradient from the Tucson Geomagnetic Observatory of the Carnegie Institution of Washington for all periods of atomic tests through 1953 revealed only one case in which the electric parameters of the atmosphere

were significantly altered as a result of radioactive fallout (10). Although very few observatories make continuous records of the electric conductivity of the atmosphere, observations of the increased radioactivity of the air, as well as theoretical considerations, indicate that the conductivity of the air near the ground may be significantly altered at many locations for 4 or 5 days after an atomic explosion.

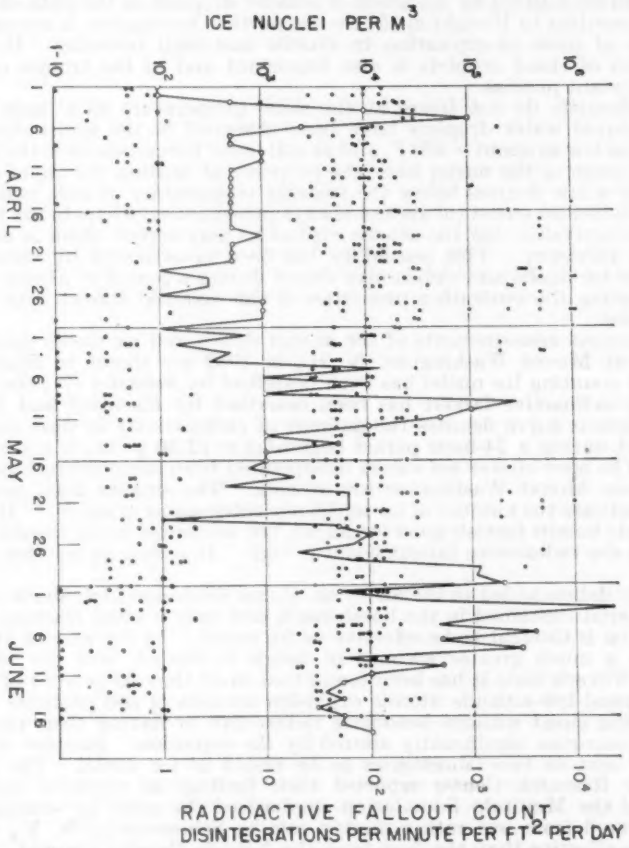


FIGURE 1. Measurements of radioactive fallout (solid line) and ice nuclei count (small dots) made at Mount Washington, N. H., in 1952. Values for radioactive fallout of 10 disintegrations/ft² min are indicative of low values and not of accurate measurements.

The average natural conductivity of the free air as determined from more than 80 aircraft observations (11) is shown by the solid line in figure 2. The extreme values recorded are shown by the dashed lines. Theoretical considerations have been employed to compute the conductivity change expected in a region of moderately high fallout of radioactive material, such as may cover a few thousand square miles outside the proving ground following one of the larger bombs. This is shown by curve A. The conductivity to be expected near the largest observed fallout outside the test area is given by curve B. The radioactive decay rate of fission products is quite rapid, and curve B would be transformed into curve A within 9 days. It is seen that this layer of increased conductivity resulting from radioactive fallout is rather shallow and is not likely to have any effect on the more directly observable weather elements (12).

However, theoretical considerations indicate that under extreme conditions the conductivity of the free air may be increased sufficiently to interfere with the charge separation mechanism in thunderstorms in such a way that the amount of lightning produced by a given cumulonimbus cloud will be reduced. Unfortunately no evidence for checking this hypothesis (12) has been found.

No observational evidence or theoretical reasons have been found for believing that changes in the electric conductivity of the air will lead to any directly observable changes in the weather other than the possibility of decreasing the amount of lightning.

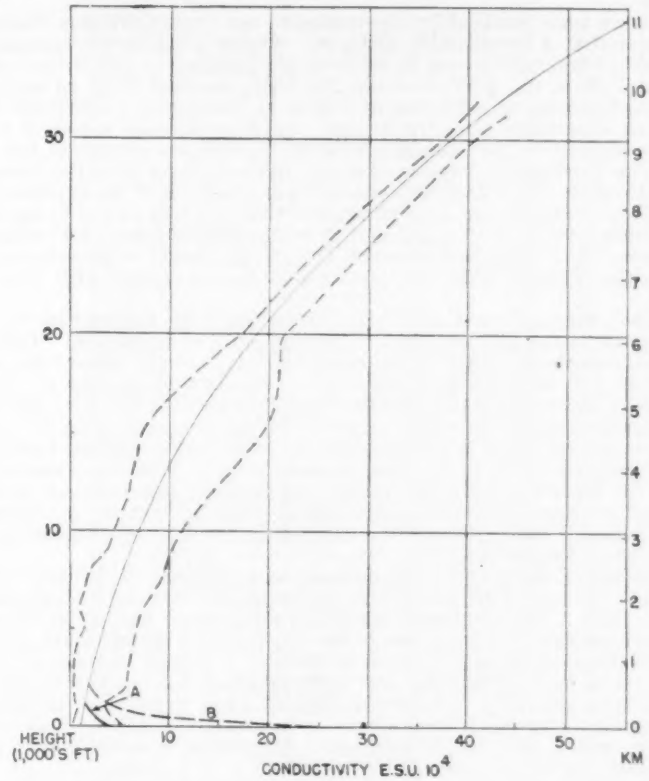


FIGURE 2. Natural conductivity of the air and theoretical changes produced by fallout.

Effects on solar radiation.—Many meteorologists believe that the amount of solar radiation reaching the ground can be greatly reduced by introducing a cloud of fine dust into the upper atmosphere, and that this will lead to a reduction in the mean temperature of the earth. The eruption of the Krakatoa volcano in 1883 threw several cubic miles of debris into the air. This was followed by a reduction in solar radiation measured at the ground (13).

However, according to the best available information, there appear to be many orders of magnitude separating the amount of dust required to produce any significant reduction in the worldwide incoming radiation and that produced by the Nevada explosions.

Effects of the explosion itself.—None of the scientists who replied to the inquiry about A-bombs and weather felt that the energy of the explosion could have a significant effect on the weather. A few comparisons between the energy of an A-bomb and natural phenomena can help explain their position.

The energy of a nominal A-bomb (equivalent to 20,000 tons of TNT) is 2×10^{13} cal. (2). This is divided into thermal and kinetic energy although the latter will also ultimately be converted into thermal energy. The thermal energy from the sun falling on 1 mi^2 of Nevada ground during an average spring day supplies as much heat as two nominal bombs. The energy released by the condensation of water in a typical thunderstorm is equivalent to 13 nominal bombs. Further comparisons with natural phenomena reveal similar statistics suggesting that the energy of an A-bomb, while tremendous compared with the energy of other manmade explosions, is relatively small compared with that of many natural phenomena.

The pressure wave emitted by the explosion may cause pressure changes that can be detected at a considerable distance. Figure 3 shows the response of the Bishop, Calif., barograph (about 80 mi from ground zero) to two of the explosions. The rise at 7:20 a. m., PST, October 30, 1951, resulted from an explosion at 7 a. m. But following an explosion at 7:30 a. m. November 1, 1951, for example, there was no detectable pressure change. In general, only a few of the shots have been recorded on the standard weather barographs outside of the proving ground. The movement of these pressure waves depended on the temperature and wind structure of the atmosphere as well as the force of the explosion.

Observational evidence.—It may be argued that the weather is being modified by the A-bomb tests in spite of our finding no theoretical reason for believing this to be the case. It is therefore necessary to inspect climatic records to detect any changes in the weather that may reasonably be connected with the Nevada bomb tests.

The climatic element most often cited as having been changed by the atomic testing program in the United States is the frequency of tornadoes. The number of tornadoes reported in 1953 (532) exceeded the previous highest annual total by more than 200 and 686 were reported in the first 10 months of 1954. An examination of the weather patterns for the spring months of 1953 indicates that 1953 had many features in common with several previous years of unusually high tornadic activity, and it is likely that these favorable weather patterns contributed to making 1953 an unusual tornado year. A careful examination of the system for reporting tornadoes reveals considerable improvement since 1950, with perhaps the greatest improvement taking place in 1953 and continuing into 1954; it is believed that much of the increase in tornado reports can be traced directly to these changes (14).

Using the loss of life or property damage as a measure of tornado incidence, one finds that the loss of life in 1953, 516 persons, was exceeded on several occasions before 1950. The number of tornadoes doing more than $100,000 in damage, 43, was exceeded in 3 years before the beginning of atomic tests in Nevada, despite the increased property values in 1953. The total damage of 1953 did reach an all-time high of $224,345,900 because about 7 tornadoes struck exceptionally valuable property. However, none of these extremely damaging tornadoes occurred under the atomic cloud or in areas of relatively high fallout of radioactivity, and 1 occurred in December, more than 6 months after the last atomic explosion in Nevada.

One significant feature of the 1953 tornado observations is the reporting of 133 tornado funnels that failed to touch the ground—more than 10 times the average number of funnels aloft reported in earlier years (fig. 4). This seems to be an indication of increased interest in tornado reporting.

A detailed study of the relationship between areas of radioactive fallout, or the presence of atomic clouds, and tornado occurrences reveals that there were relatively fewer tornadoes reported in areas of the atomic clouds or areas of large radioactive fallout than in areas of relatively small fallout. Furthermore, if one assumes that the increase in tornado reporting efficiency is approximately constant throughout any given year, the fraction of the annual number of tornadoes occurring during the Nevada test periods can be shown to be slightly less than in corresponding periods prior to 1950 (14). Neither of these statements is to be interpreted as proof that the presence of atomic debris inhibits tornadoes, but rather as convincing evidence that a case cannot be made for the A-bombs increasing the likelihood of tornado occurrence.

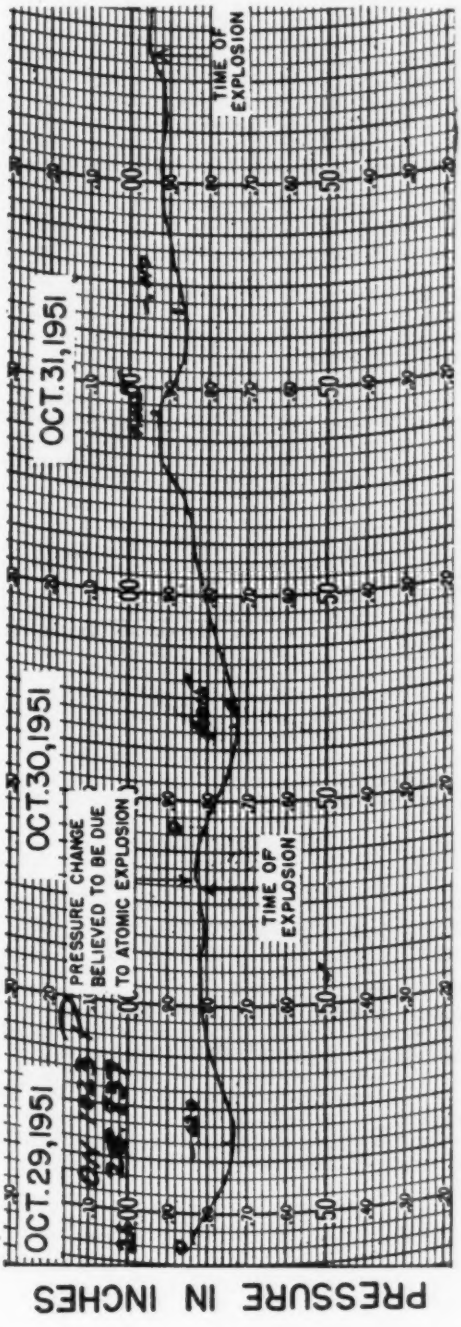


FIGURE 3. Microbarograph records for Bishop, Calif., October 29 to November 1, 1951.

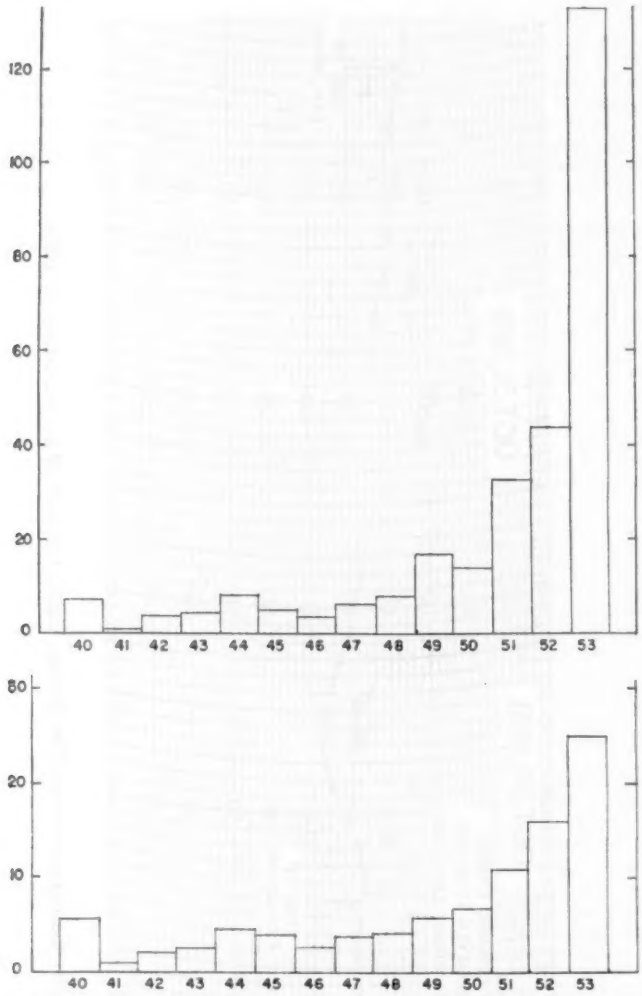


FIGURE 4. Top: number (ordinate) of reported tornado funnels not touching the ground, 1940–53 (abscissa). Bottom: percentage (ordinate) of reported tornado funnels not touching the ground, 1940–53 (abscissa).

The upper curve in figure 5 shows a plot of the monthly departure of the mean temperature of the entire United States from the average value for the period 1893–1950. The only record-breaking temperature in this curve since 1950 is the value of 42.9° F. (8.4° above normal) in February 1954, which occurred many months after the last preceding Nevada atomic explosion. This curve shows the beginning of a trend toward warmer temperatures beginning early in 1951, and apparently continuing to the present. This is clearer in the curve for annual mean temperature shown in the lower part of figure 5. The heat released by an atomic bomb is certainly not enough to account for this warming; on the other hand, one of the most frequently suggested means by which the atomic bomb might affect the weather—by decreasing solar radiation—would imply lower, not higher, temperatures as the result of an atomic explosion. It may be noted that the trend toward warmer temperatures was even more pronounced during the period 1932–34.

The upper curve in figure 6 is a plot of the average monthly precipitation for the entire United States, plotted as a percentage of normal. The normal was computed from the data for the period 1893–1950. The only exceptional point on this graph since 1950 is the value of 26 percent of normal precipitation in October 1952. This was by far the driest month in the period of record. It occurred 4 months after the last atomic explosion in Nevada and at a period when there was little or no debris from atomic explosions over the United States. Although most suggested theories of the effect of atomic explosions on weather imply an increase in rainfall, this curve indicates a tendency toward drier than normal weather beginning in 1952. This trend can be seen more clearly in the curve for annual precipitation in the lower part of figure 6. Rainfall in the United States has tended to be below normal since the beginning of 1952, and 1952 was the driest year since 1930. However, 1910 and 1921, as well as 1930, were drier than 1952, and there have been several periods since 1893 when the accumulated deficiency of precipitation was comparable to that recorded since 1952. The ultimate causes of these earlier periods of dry weather are also unknown. However, atomic explosions could not have caused them, and there is little reason for believing that the current dry spell has been brought on by the atomic explosions. A study of a series of individual weather stations reveals no results that differ significantly from the country-wide averages.

Pacific tests.—This discussion has been limited to the effects of atomic explosions in Nevada because we have not yet examined sufficient data from the most recent Pacific tests to justify more than a tentative conclusion. However, a preliminary examination of the data does not indicate that any obvious changes in the weather have been produced by these explosions outside of the test area. This study is being continued.

Conclusions.—A number of suggested mechanisms by which atomic explosions might affect weather have been investigated and a study of climatological data has been made to determine whether any weather anomalies exist that might be associated with atomic explosions. Although it is not possible to prove that atomic explosions have or have not influenced the weather, it is believed that this study has shown that such an effect is unlikely. The results of this study may be summarized as follows:

(1) No theoretical reason has been found for believing that any of the mechanisms examined could account for a significant change in the weather more than a few miles from the site of the explosion.

(2) The year 1953 was an unusual tornado year. Although part of the increase in the number of tornadoes reported in 1953 may have been the result of exceptionally favorable weather patterns for tornadoes, much of the increase can be attributed to improvements in the method of collecting tornado statistics.

(3) A study of the temperature and precipitation records for the United States does not seem to indicate any departures from normal that are related to the atomic explosions.

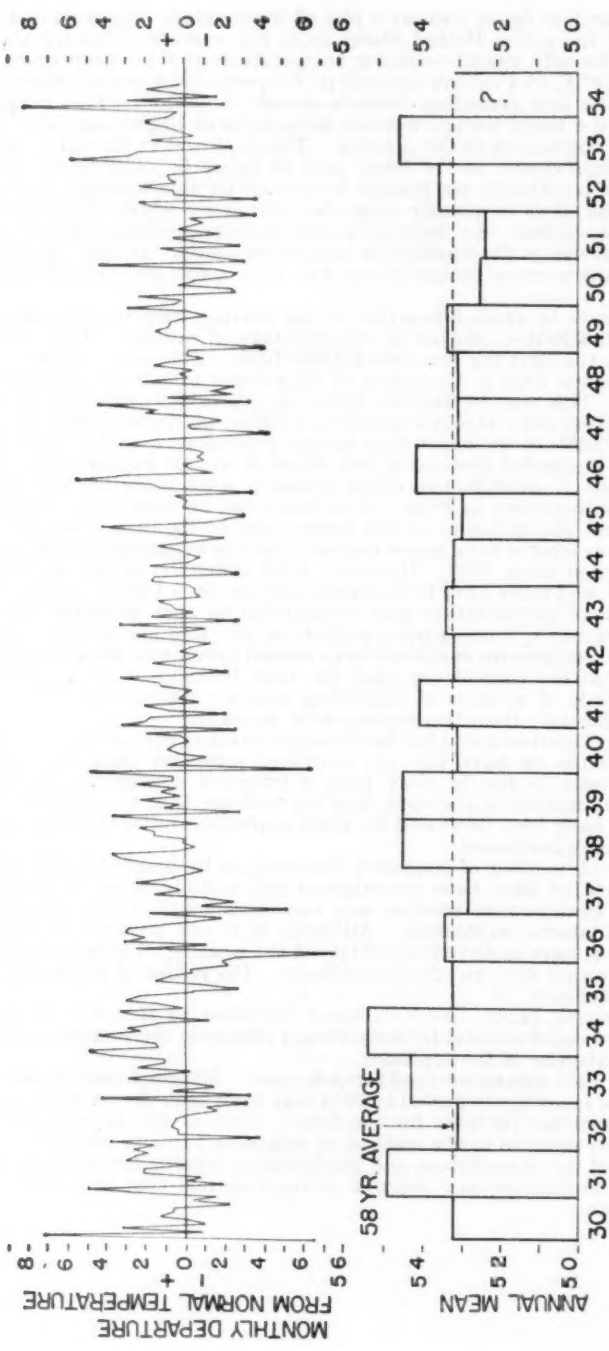

MONTHLY DEPARTURE FROM NORMAL TEMPERATURE
ANNUAL MEAN
58 YR. AVERAGE
?
30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54

FIGURE 5. Top: departure of the monthly mean temperature from the 58-year average. Bottom: average annual mean temperature, 1940–53.

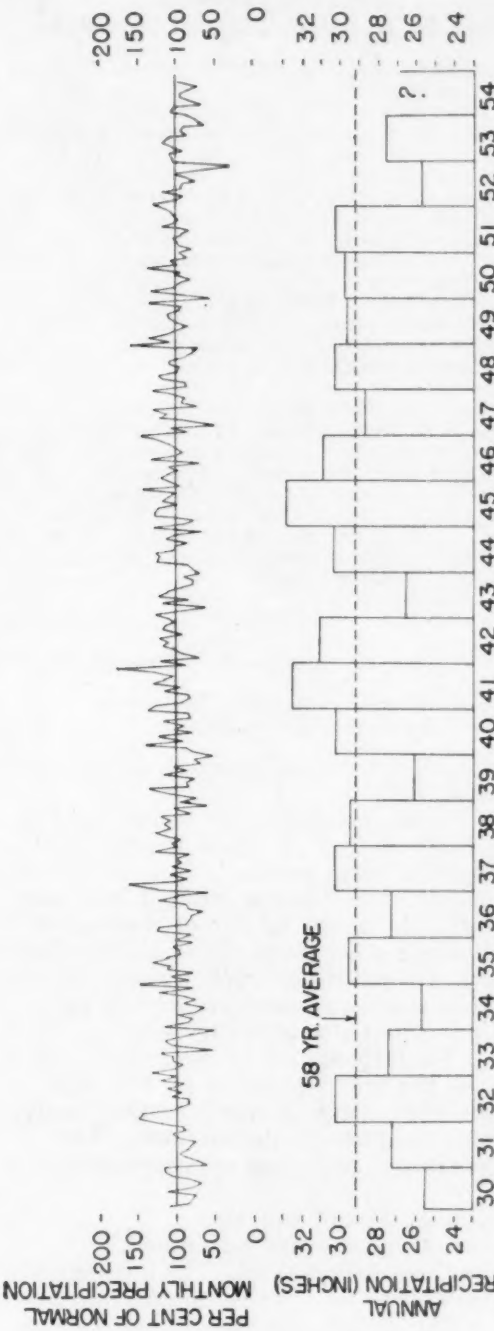


FIGURE 6. Top: percentage of normal monthly precipitation. Bottom: average total annual rainfall for the United States, 1930–53.

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1. A. A. Cumberledge, *Sci. Monthly* 64, 135 (1947); B. Holzman, *Weatherwise* 4, 3 (1951).

2. Atomic Energy Commission, *The Effects of Atomic Weapons* (Government Printing Office, Washington, 1950).

3. R. J. List, *Bull. Am. Meteorol. Soc.* 35, 315 (1954).

4. We wish to express our appreciation to the Atomic Energy Commission for making available much of the data used in this study; to Vincent J. Schaefer for testing the nucleating effectiveness of the Nevada soil samples and for providing the records of ice nuclei observations at Mount Washington; to the personnel of the Cloud Physics Section of the Air Force Cambridge Research Center for testing the nucleating efficiency of soil samples and atomic radiations; and to the Carnegie Institution of Washington for permission to use the records of the Tucson Geomagnetic Observatory.

5. H. G. Houghton, *J. Meteorol.* 7,363 (1950).

6. Some writers distinguish between *freezing nuclei*, which cause existing water droplets to freeze, and *sublimination nuclei*, which permit the direct sublimination of water vapor. In this article both freezing and sublimination nuclei are referred to as *ice nuclei*.

7. V. J. Schaefer, *Bull. Am. Meteorol. Soc.* 35, 230 (1954).

8. M. Eisenbud and J. H. Harley, *Science* 117, 141 (1953).

9. It is noted that there are many ice nuclei counts of less than 500 or greater than 2,000/m^3, but almost none in between. The reason for this has not been explained, but it may be the result of the fact that one method of observation is used for high values and another for low values. Presumably no satisfactory techniques have been found for the in-between region. Thus the values of ice nuclei concentration below 1,000/m^3 are to be taken as indicative of rather low values and not as accurate measurements.

10. D. L. Harris, *J. Geophys. Research*, in press.

11. R. C. Callahan *et al.*, *ibid.* 56, 545 (1951); R. C. Sagalyn and G. Faucher, *J. Atmospheric and Terrestrial Phys.* 5, 253 (1954).

12. D. L. Harris, unpublished report on the effects of atomic explosions on atmospheric electricity.

13. W. J. Humphreys, *Physics of the Air* (McGraw-Hill, New York, 1940); H. Wexler, *Bull. Am. Meteorol. Soc.* 32, 10 (1951); ———, *ibid.* 32, 48 (1951); ———, *Sci. American* 186, 74 (1952).

14. D. L. Harris, unpublished study of the effects of atomic explosions on the frequency of tornadoes in the U. S.

Mr. STRAUSS. We have nothing more to present, Mr. Chairman, but we are very greatly obliged for this opportunity which the committee has afforded us to make the statement and present testimony.

Representative PRICE. Mr. Strauss, while I was home during the Easter holidays, and right in the middle of the Nevada test, the St. Louis area, and I imagine other parts of the Middle West, had a very severe earth tremor. I recall it very well, about 7:15 on the morning of April 9. Of course, there was considerable talk about it and many of the people attributed that also to the tests in Nevada, as they have some other things. Would you care to comment on that?

Mr. STRAUSS. It is the first I heard of it, Mr. Price. I am under the impression that the energy in earthquakes vastly exceeds the energy in thunderstorms or atomic detonations. That is a release of energy on a very enormous scale, not approached by any man-made releases.

Representative PRICE. Thank you, sir.

Chairman ANDERSON. Thank you very much.

We will terminate the hearings then. The hearings will be printed, and they will be available so that in case the Atomic Energy Commission or the Weather Bureau has requests on these specific points, they may be distributed by your agencies as well as our own.

Thank you all very much.

(Whereupon, at 3:20 p. m., Friday, April 15, 1955, the hearings were concluded.)

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